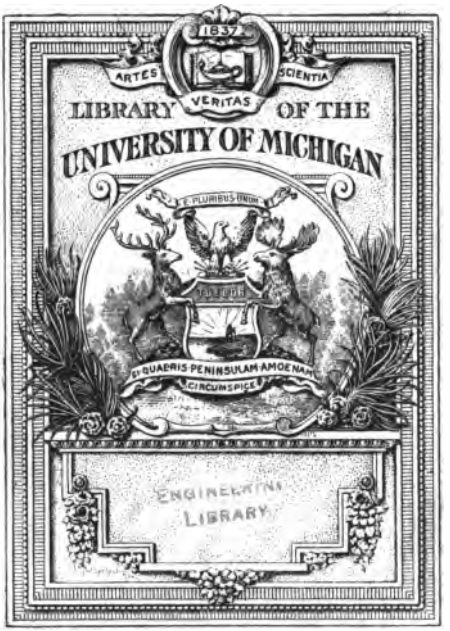
U. S. BRIDGE EQUIPAGE

AND

PONTON DRILL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OF

THE BRIDGE EQUIPAGE

OF THE

UNITED STATES ARMY,

WITH DIRECTIONS FOR

THE CONSTRUCTION OF MILITARY BRIDGES.

PREPARED BY A BOARD OF ENGINEER OFFICERS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1870.
REPRINTED, 1898.

OFFICE OF THE CHIEF OF ENGINEERS,
UNITED STATES ARMY,
Washington, June 15, 1898.

SIR: I have the honor to recommend that 500 copies of "System of Bridge Equipage and Directions for its Manœuvre," with illustrations, prepared under the orders of the Chief of Engineers by a Board of Engineer Officers in 1869, and, with the approval of the Secretary of War, determined and established for the Engineer Service of the Army, be reprinted at the Government Printing Office, upon the usual requisition, for the use of this office, for distribution to engineer officers in the field.

This manual is a necessity in connection with the use of ponton trains, and there is a great demand for it. The former edition is entirely exhausted.

Very respectfully, your obedient servant,

JOHN M. WILSON,
Brig.-Gen. Chief of Engineers,
U. S. Army.

Hon. R. A. ALGER,
Secretary of War.

Approved.
R. A. ALGER,
Secretary of War.

GEN. ORDERS, No 6. } HEADQUARTERS CORPS OF ENGINEERS,
Washington, D. C., Nov. 15, 1869.

The following system of *Bridge Equipage and Directions for its Manœuvre*, prepared under the orders of the Chief of Engineers by a Board of Engineer Officers, is, with the approval of the Secretary of War, hereby determined and established for the Engineer Service of the Army.

A. A. HUMPHREYS,
Brig. Gen. and Chief of Engineers.

WILLETS POINT, NEW YORK,
Engineer Depot, June 30, 1869.

Brig. and Bvt. Maj. Gen. A. A. HUMPHREYS,
Commanding Corps of Engineers.

GENERAL: The Engineer Board convened by Special Orders, No. 168, dated Headquarters Corps of Engineers, December 19, 1868, has the honor to submit the following report on the construction and organization of bridge trains for the armies of the United States, and on the methods of constructing military bridges of all kinds, with or without the bridge equipage—including a complete manual for the instruction and drill of pontoniers.

Very respectfully, your obedient servants,

J. C. DUANE,
Lieut. Col. of Engineers and Bvt. Brig. Gen.

HENRY L. ABBOT,
Major of Engineers and Bvt. Brig. Gen.

WILLIAM E. MERRILL,
Major of Engineers and Brevet Colonel.

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LIST OF PLATES.

NOTE.—These plates, contained in a separate atlas, are drawn upon a sufficiently large scale to serve for working drawings. Copies of those especially needed in the instruction of engineer troops, (Plates XI to XVI, inclusive,) reduced to half-size by the photo-lithographic process, are bound in this volume.

INTRODUCTION.

The following brief history of the steps which have been taken, in this country, to organize a bridge equipage adapted to our service, will sufficiently explain the reasons that have induced the Board to recommend the system described in the following report.

Previous to the Mexican war, no attempt was made to organize a bridge equipage in our service. During this war, two complete trains of india-rubber pontons were constructed and sent into the field. At its close these trains were sent to West Point, where they were used for the instruction of cadets and engineer troops. A full description of this equipage is given in the "Professional Papers, Corps of Engineers, No. 4."

It soon became evident that india-rubber was not at all adapted to the construction of pontons—

First. From the perishable nature of the material. The cylinders are formed of alternate layers of canvas and india-rubber. The sulphur used in the process of vulcanization generates sulphuric acid, which soon destroys the fabric of the cloth.

Second. The extreme elasticity of this species of support gives to the bridge a rocking and oscillating motion, so violent as to render it unsafe for the passage of animals.

Third. The most serious objection, however, is that a puncture, either above or below the water-line, is equally fatal to the cylinder. Hence, a single sharpshooter, from a rifle-pit on the enemy's side of the stream, can destroy these pontons as fast as they are launched.

In the autumn of 1858 the india-rubber pontons having become entirely unserviceable, experiments were made to determine the composition of a bridge equipage that should be adapted to our service. In conducting these experiments, the following fundamental rules were kept constantly in view:

First. The mobility of the train must be such as to enable it

to keep pace with all the movements of the column to which it is attached.

Second. The train should furnish the means of ferrying troops promptly and safely, as in the case of disembarkations and the passage of a river by force.

Third. It should furnish the means of constructing a bridge capable of passing an army with all its trains over the largest and most rapid rivers, with safety and without delay.

Now, under the most favorable circumstances, it is very difficult to reconcile the first and third of these rules, when but one species of ponton is employed. In this country it is impossible. The immense trains with which our armies are unavoidably encumbered, the long marches to be made, and the numerous wide and rapid rivers to be crossed, demand an equipage of the most substantial character. On the other hand, the extended expeditions of light columns, which necessarily attend our military operations, require a train light enough to keep pace with the most rapid cavalry movements.

Hence we require both a reserve and advance-guard train.

The experiments above named included the trial of samples of the bridge equipages used by those European armies most experienced in the art of military bridge-building.

Pontons were constructed after the models of the French bateau, the Austrian sectional ponton, and the Russian canvas boat. Corrugated-iron boats were procured, corresponding as nearly in form and dimensions to the French and Austrian boats as the nature of the material would permit. A number of Birago trestles were also constructed. All of the above material, with the exception of the iron boats, was prepared by the enlisted men of Company A, Engineers.

The bridges formed of this material were exposed as much as possible to the action of heavy loads, storms, the tide, and floating ice. The material was also packed on carriages of various patterns in order to ascertain the best form, both of bridge material and of carriage, for transportation.

The selection of the French, Russian, and Austrian trains for these experiments, was made after a careful study of the various equipages used at present by the armies of Europe. These three nations alone appeared to have definitely settled on their systems, and this after much experience and thorough research.

The Prussians and Spaniards were seeking for substitutes for

their bridges, which had proved unsatisfactory. The Sardinians had adopted a plan inferior to that of the Austrians, though similar in some respects. The English tin ponton had too many of the defects of the india-rubber to answer our purposes.

After experimenting for two years with the above-mentioned material, the following conclusions were reached: The French ponton is superior to the Austrian in simplicity and stiffness; as a ferry-boat, it will transport more troops and is more easily managed; in the bridge its superiority is marked. With the French equipage, the corresponding balks of the adjacent bays lap each other about six feet, and are firmly lashed together and to both gunwales of the ponton, which greatly increases the strength and stiffness of the roadway; while with the Austrian, the balks must meet on a sill directly over the axis of the boat. The bays thus hinging on this sill, full play is allowed to the horizontal and vertical oscillation to which floating bridges are subject.

As to land transportation, the French train requires fewer carriages to transport the same length of bridge than the Austrian, since for each section of the latter ponton a separate vehicle is necessary. The length of the two carriages does not differ materially, this being determined by the length of the balks.

These considerations led to the adoption of the French ponton.

The next question was, what material should be employed in its construction. Lifeboats having been successfully manufactured in this country out of corrugated iron, it was presumed that this material could be used with equal advantage in the present case. The first boat, made of the same thickness of metal as the largest class lifeboat, proved to be deficient in stiffness when placed in the bridge. The corrugations, running from bow to stern, diminished the power of the sides to resist the vertical strain caused by the weight of the roadway on the gunwales. To remedy this defect, it was proposed to line the boat amidships with iron corrugated vertically or to introduce strong iron ribs.

These expedients, though they would have increased the weight beyond that of the wooden ponton, might have been successful, but they were not attempted, as the boat failed in other respects. In fact, it would not bear land transportation; as, in

travelling over a rough road, the joints open, either the rivets or sheet iron giving way. When in the bridge, if the boat grounds on an uneven or rocky bottom, a hole is frequently punched through it, and such injuries can not be repaired in the field. The wooden ponton is not only much less liable to such accidents, but can be readily repaired when they do occur.

Previous to the battle of Gettysburg, a ponton bridge over the Potomac at Harper's Ferry was destroyed, the ponton being scuttled and set adrift above the rapids. About three weeks after, the water having fallen, the boats were recovered, repaired with pieces of hard-bread boxes obtained from the commissary, and used in constructing a bridge at Berlin, over which the entire Army passed into Virginia.

With regard to the canvas boat, it soon became apparent that it was precisely what we required for our advance-guard train. It is light, simple, strong, easily repaired, and when packed can safely be transported with the superstructure of the bridge as rapidly as any column of troops can move. A strong argument in favor of its adoption was that it had been used successfully by the Russians for more than a hundred years, under every variety of circumstances likely to occur in this country.

The selection of the carriage for transporting the bridge material was next taken up. The French ponton wagon is not adapted to our rough roads. The wheels are too small, and can not be increased in diameter without raising the load too high above the ground.

A carriage was finally devised on the principle of the four-horse truck used in the city of New York. By means of the horizontal fifth wheel over the front axle, and of an inclined wagon bed, forward wheels of the requisite size were enabled to reverse completely under the load, thus allowing the carriage to turn in a short space. This construction is absolutely necessary when so long-geared wagons travel over a crooked road.

For the chess wagons and canvas train, a similar wagon would, without doubt, have answered the purpose perfectly, so far as transportation was concerned; but the ordinary baggage wagon of the Quartermaster Department, with some modifications, was used on account of the facility with which it could be obtained and the readiness with which spare parts could be procured for repairs in the field.

The Birago trestle, which had been recently adopted by most

of the European nations, was also thoroughly tested; and, the result proving favorable, it was proposed to employ it in connection with the pontons of both trains.

From the information gained by these experiments, there resulted the system of bridge equipage adopted at the commencement of the late war. During the winter of 1861–62, five trains were constructed, each composed of thirty-four pontons and eight trestles—the pontons being nearly of the same form and dimensions as the French bateau. The frame was somewhat different, the ribs being entire and strongly ironed, and the ironing stronger throughout. The stern was provided with a locker. There were also other alterations in the details of construction. The balks were stronger; and the Birago trestle was modified by substituting built beams, instead of solid timber, for the trestle caps and balks.

At the same time several canvas trains were organized. In constructing the ponton frame, the dimensions and form of the Russian boat were exactly retained. The scantling for the frame was considerably lighter, but, being strongly braced and ironed, the strength was about the same. One train was composed of canvas boats and trestles; being, in truth, a trestle train, with auxiliary pontons to be used only where the depth of water, or muddy bottom, prevent the use of trestles.

In the month of February, 1862, a ponton bridge, composed of about sixty boats of the reserve train, was thrown across the Potomac at Harper's Ferry. The river was then a perfect torrent, the water being fifteen feet above the summer level, and filled with drift-wood and floating ice. The greatest difficulty was experienced in pulling the pontons into position, and it was necessary to make use of ship anchors and chain cables to hold them in place. Notwithstanding these unfavorable circumstances, the bridge was completed in about eight hours, and the corps commanded by General Banks, with all its trains and artillery, passed over it without accident or delay.

Several of these trains accompanied the Army in the Peninsular campaign. The pontons were used in discharging quartermaster and commissary stores at Ship Point; in disembarking General Franklin's command at West Point; and in constructing bridges over Hampton Creek, the streams in front of Yorktown, and the Upper Chickahominy. Finally, a bridge was built over the Lower Chickahominy, about two thousand feet long, over which nearly the whole army of the Potomac,

with its immense trains, artillery, and cavalry, passed with promptness and safety.

After the army had passed, the bridge was dismantled and the balks, chess, etc., packed into the pontons, which were formed into rafts and towed by steamers to Washington. The bridge trains were next transported to Harper's Ferry, where a bridge was constructed a second time, but under entirely different circumstances from that built during the previous winter. The water was now not deep enough; and, as it continued to subside shortly after the bridge was laid, many of the pontons grounded on a very uneven and rocky bottom. Some of them were completely out of water, yet the heavy trains continued to move over the bridge without seriously injuring them; and when the water rose, most of them floated as well as ever.

Discovering in this way that the boats were much stronger than we had supposed, we were enabled to improve the method of bridging tidal streams.

It had formerly been considered necessary to build out to low-water mark with trestles, so that the ponton should always be afloat. The bridge is now commenced at high-water mark, building with pontons alone. As the water subsides, the pontons nearest shore ground successively, forming a gentle ramp from the abutment to the floating portion of the bridge, instead of making the descent in twenty feet, as formerly. This method, of course, applies only to wooden pontons, and to cases where the bottom is favorable.

During the Fredericksburg campaign, it became necessary to force the passage of the Rappahannock. The enemy having entrenched themselves on the bank, prevented for some time the construction of the bridge; until, at length, troops were embarked in the pontons and ferried across, where they stormed the rifle-pits and held them until the bridge was completed.

During the year 1863 the ponton trains accompanied the army in all its marches backward and forward through Virginia. frequently bridging the Potomac, Rapidan, and Rappahannock. In the latter stream the bridges remained in position all winter, and, notwithstanding the frequent floods and the quantity of ice formed, but few interruptions occurred upon these thoroughfares.

During the campaign of 1864 trains composed of fourteen pontons and two trestles accompanied each of the three army

corps of the Army of the Potomac. These trains attended their corps in the long march from Culpeper to the James River; and, although the roads were frequently very bad, in no instance did they delay the march of the troops or arrive late when a bridge was to be laid.

The headquarters train was followed by a canvas train, which, when a crossing was to be made by surprise, was sent forward with the cavalry, who covered the construction of the bridge and held the position till the main body arrived.

On reaching the James River, a bridge was laid, opposite Charles City Court-House, about two thousand feet in length. The water was so deep and rapid that the pontons could not be held by their own anchors, and it was found necessary to attach their cables to schooners anchored above and below the bridge.

Thus the wooden ponton train, through four years of war during which the bridges constructed were without parallel in number and magnitude, amply fulfilled all the requisites of a good bridge equipage. The frequent crossing of the Chickahominy, Potomac, and James rivers proved that, even under the most unfavorable circumstances, it could furnish a bridge capable of passing a large army with its heaviest trains over wide and rapid streams with safety and despatch.

Its capabilities in ferrying troops were shown at Ship Point, West Point, and Fredericksburg; and of the mobility of the equipage there was abundant proof in the long marches during the last two years of the war.

The canvas equipage, also, was perfectly successful as an advance-guard train. In the cavalry raids it was always able to keep pace with the columns; and, although they frequently marched hundreds of miles, it was invariably ready to furnish a prompt and secure means of crossing all the streams on their route. It also often furnished bridges for the heavy trains of the army over streams of moderate width and rapidity.

The only part of the bridge equipage which did not realize all our expectations was the Birago trestle.

As already stated, a train was organized early in the war on the Austrian principle, in which the trestle is the main dependence, the ponton being merely auxiliary. It was supposed that many streams would be encountered which could be bridged best with trestles alone, but none such were met with. In fact, when a stream is more than two feet deep, a ponton bridge may be

laid; when less than that depth, if the bottom is hard, it may be forded and no bridge is required; should the bottom be soft, the trestle legs will usually settle so as to render the bridge unsafe. As it was not deemed advisable to transport with the army a train which could only be used in exceptional cases, this description of equipage was abandoned. The trestle was, however, very useful as an auxiliary, especially with the canvas train; for, as these boats when in the bridge should never be allowed to touch the bottom, it is frequently necessary to build out several bays from the shore before sufficient depth of water can be obtained to float the ponton—and for this purpose nothing could be better than the Birago trestle, which is also equally useful for a similar purpose with the reserve train, when the river bottom is rough near the shore.

The canvas train was extensively used by the Western army, and with such success that it was proposed to employ it exclusively. Experience, however, in the East has clearly proved that this train cannot fulfil all that is required of the bridge equipage of a large army. The bridges of the Potomac and James rivers could not have been built with canvas boats, which will not resist ice and driftwood; neither are they suited to the disembarkation of troops or the passage of a river by force.

Experience would therefore lead us to concur with General Barnard in his remarks on this subject, viz:

"The numerous proposers of 'flying' bridges forget that if a military bridge is intended to be *carried with* an army it is also intended to *carry* an army, its columns of men, its cavalry, its countless heavy wagons, and its ponderous artillery. It must carry all these, and it must do it with certainty and safety, even though a demoralized corps should rush upon it in throngs.

"No make-shift expedient, no 'ingenious' invention not tested by severe experiment, no light affair of which the chief merit alleged is that it is light, will be likely to do what is required, and what the French ponton has so often done."

CHAPTER I.

PASSAGE OF RIVERS.

When an army in the field finds its march interrupted by a river, it may effect the passage of this obstacle either by fording, by ferrying in boats, rafts, or flying bridges, or by military bridges.

The selection of the place and means of crossing a river is determined by a reconnaissance, which should be as detailed and extensive as circumstances will permit.

By fords.—A river with a moderate current may be forded by infantry when its depth does not exceed three feet, and by cavalry and carriages when its depth is about four feet.

The requisites for a good ford are, that the banks are low but not marshy, that the water attains its greatest depth gradually, that the current is moderate and the stream not subject to freshets, and that the bottom is even, hard, and tenacious.

In mountainous countries the bottom is frequently covered with large stones, rendering the passage of carriages nearly or quite impracticable.

In level countries the case is often still worse, the bottom either of mud or quicksand being impassable for both men and carriages. Sometimes the bottom is composed of fine sand which is hard enough, but which by the action of the hoofs of animals is stirred up and washed away, increasing the depth until the stream becomes unfordable.

The best bottom is coarse gravel.

Fords are usually found in the wider and more rapid parts of the river.

Their position may be determined by sending a number of mounted men across wherever there is a probability of the river being shallow enough.

The most certain method is to float down the stream in a boat, keeping it in the swiftest part of the current, where the stream is usually the deepest. Over the stern a sounding-line of the proper length is hung; when this touches bottom the river is sounded across.

When the ford is discovered, the remarkable objects on the

shore should be noted, that the place may be easily recognized; and a picket should be planted at the water's edge, in order that any variation in its height may be ascertained.

Rivers which are not fordable may sometimes be rendered so, when the only obstacle is a too great depth of water over an extent of eight or ten yards, by filling in this portion of their bed with fascines loaded with stones, or with stone and gravel.

When the water is sluggish or muddy, a ford may be improved by covering the bottom with bundles of coarse grass, rushes, or twigs.

There have been instances of rivers rendered fordable by diverting a portion of the water from its natural course.

When the stream is wide and rapid, the ford must first be carefully examined and staked out. The troops pass in column, with sufficient intervals to avoid choking the current.

When boats are to be had, a few should be stationed below the ford to assist men who may be carried down by the current.

When boats are wanting, this duty may be performed by mounted men, or a life-line may be stretched across, supported on casks or other floats. The force of the current may be broken, in a measure, by stationing cavalry in the stream just above the point of crossing.

After a freshet the ford should be re-examined, lest some alteration may have taken place in the bed of the river.

In marching in retreat it is frequently advisable to destroy a ford after having used it. This may be effected by digging trenches across it, or filling in the deepest part with harrows, teeth up, planks filled with spiks, crow's feet, etc.

Upon ice.—In high latitudes, during the winter, rivers are frequently covered with ice of sufficient thickness to sustain the heaviest loads. This means of communication should be used with great circumspection. A change of temperature may not only suddenly destroy this natural bridge, but render the river impassable by any method for a considerable time, in consequence of the floating ice.

The thickness of ice should be, to allow the passage of infantry in single file on a line of planks, and two yards apart, two inches; cavalry, or light guns, with intervals, four inches; 12-pounder field-pieces, unlimbered and on sleds, five inches; 12-pounder field-pieces, limbered and drawn by horses with intervals between pieces, six to seven inches. Ice when ten to twelve inches thick bears the heaviest loads.

Two tracks of planks laid on the ice for the carriagewheels to run on, may be employed when there is any doubt as to its strength, or the wagon may be transformed into a sort of sled by fastening two planks under the wheels.

The thickness of the ice may be increased, when the temperature is low enough, by throwing water on it.

When the river is frozen on each side, but open in the middle in consequence of the velocity of the current, a boom stretched across the open space will often check the velocity sufficiently to cause the water to freeze.

Passage on boats, rafts, etc.—The point of passage being selected, all the boats that can be procured will be collected. In default of a sufficient number of them, lumber, casks, and other material suitable for rafts, should be procured, and the rafts be constructed without delay. The banks, if too steep, will be cut down; the landing on the opposite shore should be further down the stream than the point of embarkation, as the loaded boats will drift with the current. The boats will be arranged along the shore according to size, and numbered; the rafts should be moored below the boats.

The infantry will be divided into sections, depending in size upon the capacity of the boats in which they are to embark; each section will be provided with the number of its boat; great care must be taken not to overload the boats or to crowd the boatmen.

The soldiers will enter the boats one by one, alternately against the right and left gunwale; they will be cautioned not to stir from the places assigned them, and above all not to spring up when the boat lurches; they will disembark in the same order, *i. e.*, one by one.

When the river is shallow near the shore, the boat must not approach the bank near enough to ground as the men file in.

In the passage of artillery it is usually necessary to dismount the piece.

Horses are not often passed over in boats, since they may usually be more conveniently made to swim. When boats of sufficient size are available, their bottoms must be covered over with plank, and the horses be placed crosswise, facing alternately up and down stream; otherwise they may be thrown down by the rolling of the boat.

Rafts.—The passage of all arms may be facilitated by con-

structing a floating bridge, formed of two boats covered with a platform constructed as follows:

From five to seven beams of the same thickness are laid across the two boats, the interval between the beams being equal, and such that the covering planks extend one foot beyond the extreme beams.

The interval between the boats is such as to allow the beams to extend two feet beyond the outer gunwales. The beams are lashed to the boats; the covering planks are kept in place by two side-rails laid directly over the outer beams and lashed down to them; the extreme planks are nailed down.

The size of the beams is regulated by the load, and the interval between the boats. With seven beams twenty-seven feet long and five inches square, and covering-plank one and a half inch thick, a 24-pounder may be carried.

Not only may artillery and cavalry be transported by this means, but also infantry in much greater numbers than by using the boats separately. The floating bridge can be manœuvred by oars with nearly the same facility as a boat.

The same rules apply to the passage of troops on rafts as in boats, attention being paid to the following circumstances: that rafts drift more than boats, consequently the landing on the opposite shore will be further downstream; and that, as the embarkation is easier, there is more danger of overloading the raft and of confusion in embarking. Infantry enter by the flank and occupy first the middle of the raft, through its entire length; a rank is then added alternately on the up and down stream side until the raft is loaded.

Artillery and heavy carriages are placed in the centre, and cavalry as in the boats.

Rafts possess these advantages over boats, viz: the embarkation and landing of all arms are easier; they carry large numbers at each trip; they are not easily injured by the fire of the enemy; they draw little water.

They cannot, however, be navigated with the same facility as boats, and move much more slowly through the water, thus keeping the troops a longer time under fire when in the presence of an enemy.

They cannot be directed with certainty on a fixed point when the stream is rapid, and in this case it is often impossible to bring them back against the current to the starting point.

Finally, the length of time required for their construction forbids their use when the passage is to be effected secretly.

When the material is limited in quantity, the passage will be executed more readily by means of the rope ferry, trail or flying bridge.

The rope ferry, which is used in streams with sluggish currents, consists of a floating support, either raft, floating bridge (as described above), or a wide scow. It is drawn by hand along a rope stretched from bank to bank.

The trail bridge is employed on streams of not more than one hundred and fifty yards in width, and with a current whose velocity is not less than one yard per second. The rope must be maintained above the surface of the water, and consequently must be drawn very tight by means of windlass, blocks and falls, or similar expedients; it must also be raised at each bank some distance above the water.

The raft or boat is attached to a pulley which runs on a sheer line, and by means of a rudder is given such a position that its side makes an angle of about 55° with the direction of the current.

The force of the current exerted on the side of the float may be divided into two components, one perpendicular to the sheer line, which is destroyed by the resistance of this line, the other parallel to it, which causes the float to cross the stream with a velocity depending upon the strength of the current.

The most suitable float for the purpose is one composed of two long, narrow, and deep boats, with nearly vertical sides. The interval between the boats is such that the current shall act on the sides of both through their entire length, when they form the proper angle with it.

When timber rafts are used they should have the form of a lozenge, whose acute angle is 55°. When two sides are parallel to the current, the up stream side will then be in the most favorable position for the passage.

Flying bridge.—When the river is more than one hundred and fifty yards in width, the strain on the sheer line would be very great; it is, therefore, usually replaced by a cable, one end of which is attached to the float and the other anchored in the stream, thus forming a flying bridge.

The cable is supported by several floats, either small boats or barrels, logs, etc.

When an anchor is used, the first float should be as near it as

possible without danger of tripping it; the others should be so arranged as to maintain the cable above the water. The cable is anchored in the middle of the stream when the current is stronger there; but when stronger near one shore, it must be anchored nearer the other. If no floats for the cable are used, it must be passed over a gallows frame on the raft to keep it from dragging in the water.

The flying bridge is manœuvred in the same manner as the trail bridge.

Rope ferries or trail or flying bridges furnish the means of passing any stream, and may be advantageously employed in many cases. They may be established without difficulty in a short time, and with limited material such as can often be found in the vicinity. They permit the passage of all arms and of the heaviest loads. They are not liable to injury from floating bodies, and the flying bridge does not interrupt navigation.

By bridges.—When a river is more than four feet in depth, or when its bottom is of mud or quicksand, recourse must be had either to ferrying by means of boats, rafts, etc., or to military bridges. The latter are always to be preferred when circumstances will permit their establishment.

Military bridges are composed of a roadway and its supports; the first consists of beams or balks reaching across the adjacent supports, and covered with plank called chess.

The supports, from which the bridge takes its name, may be either fixed, as trestle, gabions, carriages, piles; or floating, as pontons, boats of commerce, rafts, etc.

Ponton bridges are preferable to all others when a passage by main force or surprise is to be undertaken.

They may be constructed on any stream of sufficient depth.

Pontons may be replaced by rafts when the velocity of the stream does not exceed six feet per second. In swifter currents the latter are unmanageable, drag their anchors, and are liable to destruction from floating bodies.

Trestle bridges may be constructed in rivers whose depth does not exceed nine feet, and whose velocity is not more than six feet. They may be employed with advantage in rivers of moderate depth and gentle current, with hard, even bottoms. When the bed of the river is uneven, the adjustment of the trestles to the bottom is very tedious, and, if the current is

rapid, almost impossible. When the bed is of mud or fine sand, the settlement of the legs is liable to be irregular.

Gabion bridges are used over marshes and shallow streams. They consist of gabions constructed in the ordinary way, and of a height necessary to give a level road; these are placed in rows perpendicular to the axis of the bridge, are filled with stones or gravel, and are capped with a piece of timber on which the balks rest.

Pile bridges are superior in point of stability to all other military bridges, but, requiring much labor and time in their construction, they are usually restricted to securing the communications in rear of the army.

Preservation of bridges.—Military bridges being merely temporary expedients, the same solidity is not required in them as in permanent bridges. It is sufficient to give them the strength required to support the weight of the heaviest loads which accompany an army, and to resist the action of the current, which has a tendency to tear away the supports.

The first requisite is attained by giving sufficient volume to the supports if they are floating, and sufficient vertical strength if fixed, and by using balks and chess of the proper dimensions to correspond with their length between bearings.

To resist the action of the stream, a good system of anchorage, the greatest possible distance between supports, and the placing of these supports exactly in the direction of the current, are required.

An intimate connection between the parts of the roadway, and between the roadway and its supports, is also a great assistance in resisting the current; sufficient play, however, must be left to allow the bridge to accommodate itself to the action of a heavy load in passing over it, and to the action of the waves when the water is rough; otherwise, however firm the fastenings may be, they will soon work loose.

The interval between the supports is regulated not only by the strength of the balks, but also by the cross-section and the buoyant power of the supports.

The duties of an officer charged with the construction of a bridge are, to discover and collect all the material disposable for the purpose; to examine carefully the position chosen for the bridge; and to ascertain the width and velocity of the stream, and the nature of its bottom and banks. He can then determine the composition of the bridge, taking care to re-

serve sufficient material to repair damages, and to lengthen the structure in case of a rise in the water. He will then divide his force into detachments, assign to each its duty, and require each to labor at its own task without attempting to interrupt or assist that of any other.

During the progress of the work, he will not allow any unnecessary person to approach the working parties, or to step upon the bridge.

CHAPTER II.

THE BRIDGE EQUIPAGE.

The United States bridge equipage is composed of reserve and of advance-guard trains. The former are intended to accompany large bodies of troops in the field, and are provided with the material necessary for the construction of bridges of sufficient capacity to pass large armies with their heaviest trains over rivers of any size and rapidity.

The advance-guard equipage is intended for the use of light troops, such as advance guards, cavalry expeditions, etc. It is organized, both as regards material and carriages, with a view to rapidity of movement. At the same time, it is capable of furnishing a bridge which will fulfil all the requirements of troops engaged on such service.

RESERVE EQUIPAGE.

Organization.—This equipage is divided into trains, each of which is composed of four ponton divisions and one supply division. Each division is accompanied by a tool wagon and traveling forge.

Each ponton division is complete in itself, containing all the material necessary for constructing a bridge of eleven bays, or 225 feet in length.

Each of these divisions is subdivided into four sections, two of which are ponton and two abutment sections; the former contain three ponton wagons and one chess wagon; the latter, one ponton, one chess, and one trestle wagon each.

The ponton section contains the material for three bays, and should never be subdivided. The division may be increased or diminished at pleasure by changing the number of its ponton sections.

The carriages are loaded as follows:

Each ponton wagon (Plate III) contains 1 ponton, 7 long balks, 1 anchor, 1 cable, 5 oars, 2 boat-hooks, 20 lashings, 6 rack-sticks, 1 scoop-shovel, 2 small scoops, 1 axe, 1 hatchet, 1 bucket, and 20 pounds of spun yarn.

Each trestle wagon (identical with ponton wagon, see Plate VI) contains 7 long balks, 7 trestle balks, 1 trestle complete, 2 abutment sills, 2 coils of 3-inch rope.

Each chess wagon (Plate VI) contains 60 chess.

The forge is identical with forge A, furnished by the Ordnance Department.

Each tool wagon (Plate X) contains—

50 axes,	2 monkey wrenches,	1 lb. red chalk,
20 shovels,	1 sledge,	4 lbs. white chalk,
20 spades,	1 steel square,	6 sail-needles,
15 picks,	1 grindstone,	1 palm,
25 hatchets,	1 spirit-level,	6 balls twine,
4 broad-axes,	1 coil telegraph wire,	50 lbs. 6-inch spikes,
4 adzes,	1 coil 3-inch rope,	100 lbs. 6, 8, 10, and 20-penny nails,
4 cross-cut saws,	1 coil 1-inch rope,	
4 hand saws,	1 coil spun yarn,	2 sets block and falls,
12 augers (assorted),	50 lbs. iron (assorted),	2 gross each of 1, 2, and 5-inch screws,
2 crow-bars,	25 lbs. paint,	
2 caulking irons,	6 paint brushes,	1 roll canvas,
12 tin lanterns,	1 dozen chalk lines,	20 lbs. caulking cotton.

Also four boxes of carpenters' and saddlers' tools nearly identical with those furnished by the Ordnance Department for battery-wagon C. If desirable, extra stores to the amount of 500 pounds may be added to the load.

The supply division is provided with articles necessary to replace material lost or worn out, such as balk, chess, spare parts of carriages, a few complete carriages, etc.

The carriages of this division consist of ponton, chess, and tool wagons, and of forges. Their number and proportion will be determined by the nature of the country in which the army is operating, and by the proximity of the main depot.

The ponton wagon contains 17 long and 7 trestle balks. The chess wagon, 60 chess. Tool wagon No. 1 carries the same load as that attached to a ponton division. Tool wagon No. 2 contains 80 rack collars; of 6, 8, 10, and 20 penny nails, 2 kegs each; of 4 and 6 inch spikes, 2 kegs each; of 1, 2, and 5 inch screws, 4 gross each; of 1 and 3 inch rope, 2 coils each.

The loads may be increased to the extent that circumstances will permit, by adding spare parts of carriages.

The forges are of the patterns A and B issued by the Ordnance Department.

Bridge material.—The *trestle* (Plate I, Fig. 1) is composed of a cap, (Fig. 3,) two legs, (Fig. 2,) two false legs, (Fig. 7,) two shoes, (Fig. 8,) and two suspension chains. The cap is formed of two white-pine planks, 20 feet by 12 inches by 2 inches. These are connected by six blocks, of which four (*o o*) are of oak; the others are of pine. Between the latter a curved strip of pine (*c c*) is introduced. The legs are of white pine, 15 feet by 7 inches by 3½ inches, fitted at top to receive the rings of the

suspension chains, and at bottom to enter the mortise in the shoe. The shoe, which is intended to prevent the leg from sinking too deeply into the ground, is also of white pine. It is provided with a key to secure it to the leg. The suspension chains are eight feet long. They are provided with rings at one end to put over the tops of the legs, and toggles at the other for the purpose of securing them to the rings in the cap. The vacant spaces left in the mortises of the trestle cap when the legs are inserted, are filled with the false legs.

The *abutment sill* (Plate I, Fig. 6) is of white pine, 14 feet by 8 inches by 6 inches, scored to mark the position of the balks. For facility of transportation, it is provided with a ring in each end.

The *ponton* (Plate II, Fig. 1) is about 31 feet in length, with a maximum breadth of 5 feet 8 inches. It is of about nine and a half tons burden, and has sufficient capacity to transport forty men, fully armed and equipped, besides its crew of pontoniers. In the bridge, it has sufficient strength to sustain the heaviest trains that accompany an army. The details of its construction are given in the following specifications:

The floor and side timbers to be of white oak. There are twelve timbers in all—eight, 2 by 3 inches; two, 3 by 3 inches; two, 4 by 4 inches; and all should be full measurement.

The forward and aft side timbers to be finished with mooring posts 10 inches above plank-sheer, 4 inches square at top, and 4 inches in diameter at plank-sheer.

The battens (strips between the bottom timbers) to be of pine, $1\frac{1}{4}$ inches thick by 4 inches wide.

The bow and stern pieces to be of solid oak, 4 inches thick, bevelled for bottom plank to fit.

The timber plates to be fastened to the timbers by three iron rivets passing through, and well riveted—say, one rivet at each end and one at the turn of the knee. In addition to the rivets, every iron to be fastened by eight No. 18 $1\frac{3}{4}$-inch gimlet-pointed iron screws—say, four in the side timbers and four in the floor timbers.

The cavil (piece through which the hooks for fastening the balks pass) to be of oak, 1 inch thick by 4 inches wide, and to be shouldered into the side timbers $\frac{5}{8}$ of an inch.

The boat to have 7 bottom planks, 1 inch thick, running the whole length of bottom without a joint, and fastened at each timber with two iron rivet-head nails, $\frac{3}{16}$ inch thick by $4\frac{1}{2}$ inches long, driven through and clinched; and also fastened to each batten by 3-inch clinch nails driven through and clinched.

Chafing battens to be of white oak, 1 inch thick by 5 inches wide, and to be fastened with 3-inch clinch nails driven through and clinched on the inside, except at the ends, which shall be fastened by No. 18 $1\frac{3}{4}$-inch gimlet-pointed screws, say two at each end.

The eight side planks to be each $\frac{7}{8}$ of an inch thick, and to be fastened like the bottom planks; and every plank to run the whole length of the boat, and not to be pieced.

The lower side plank to be nailed to the bottom (besides the clinch nails) with 10-penny cut nails, not over 5 inches apart. Also the chafing battens to be nailed in same way (in addition to the clinch nails) to the lower side plank.

The clamp (strip that runs along the top of the timbers on the inside) to be of pine, 1 inch thick by 3 inches wide, and shouldered into the rib flush.

The plank-sheer (piece that forms the top of the gunwale) to be of oak or ash, 1 inch thick by 5 inches wide—or wide enough to cover the gunwale; to be nailed to upper side plank and to the clamp with 10-penny nails not over 5 inches apart.

Cross-braces to be of spruce, 2 inches thick by 9 inches wide, shouldered on to the timbers $\frac{5}{8}$ of an inch, and fastened at each end with three No. 18 $1\frac{3}{4}$-inch gimlet-pointed screws.

A blocking not less than 2 inches in thickness, to be put under each row-lock plate, the socket of which should be closely fitted in passing through it.

Locker in the stern to come to the first batten, where a strong bulkhead is to be made; the top plank to be well supported, so as to bear the weight of a man. Trapdoor on top to be 2 feet by $1\frac{1}{2}$ feet, with strap hinges put on with clinch nails; door to have hasp and padlock; padlock to have brass tumblers and brass keys.

Each boat to have 14 row-locks; row-lock plates to be let in flush with top of gunwale.

Bow and stern irons (shown in drawing) to pass entirely round the bottom planking, and to connect on top—all in one piece, fastened by screws.

The boats to caulked in the best manner throughout with cotton, and to be painted lead color, two coats of white lead and raw linseed oil of the best quality being used. The iron work to be covered with black asphaltum varnish. Nail holes to be puttied.

The boats are to be neatly and smoothly finished in boat style, no cracks or flaws being filled with putty, and especial care being taken to make tight joints and to avoid splitting timbers

or planks. Best quality of seasoned wood and best quality of iron to be used. When furnished by contract, the boats must be carefully inspected on the above specifications, and on all points involving good workmanship or materials.

The *balks* are of two kinds: the long balk, (Plate II, Fig. 4), which is of white pine 27 feet by 5 inches by 5 inches, is furnished at each end with a cleat or claw of oak, the grain of which crosses that of the balk; the distance between the claws is 25 feet 8 inches. The trestle balk (Plate I, Fig. 4) is also of white pine 21 feet 8 inches by 5 inches by 5 inches; it is provided with two cleats of oak at each end. The claws thus formed have 8 inches of opening, the distance from centre to centre of claws being 20 feet.

The *chess* (Plate I, Fig. 5) is a white-pine plank 13 feet by 12 inches by $1\frac{1}{2}$ inches; the width at each end for a distance of 2 feet, is reduced to $10\frac{1}{2}$ inches, thus forming a notch on each side for the passage of the side-rail lashing. The chess is secured from splitting by a rivet, $\frac{3}{16}$ of an inch in diameter, passed through each end. The middle line across the chess is marked on both sides with a fine saw cut; this is important.

Both balks and chess should be made of the best white-pine lumber free from knots, sap, or shakes, and perfectly straight-grained.

The *saddle transom* (Plate II, Fig. 2) is of white pine, 5 feet 4 inches by 8 inches by 4 inches, with a strong iron hook at each end to put over the gunwales of the ponton. There are two small cleats on the middle of the transom, forming a recess to receive the sill.

The *saddle sill* is of white pine, 14 feet by 8 inches by $5\frac{3}{4}$ inches.

The *oars* are of the ordinary form, 18 feet in length.

The *boat hook* is of the ordinary form, 10 feet in length.

The *scoop-shovel* is of steel, and of the form usually employed for shoveling grain.

The *small scoop* is the ordinary tin scoop used by grocers.

The *bucket* is of India-rubber, of the ordinary pattern.

The *rack-stick* is of hickory, 2 feet long and $1\frac{1}{4}$ inches in diameter, with a cord 4 feet long passed through one end.

The *rack-collar* (Plate II, Fig. 5) is of strap iron $1\frac{1}{4}$ by $\frac{3}{8}$ inches, made in two parts united by a link on each side. The inside measurement of the collar is 1 foot 7 inches by 5 inches.

Pickets are of oak or hickory, 3 feet long by 3 inches in diameter, protected at both ends with iron.

The *anchor* is the kedge, weighing 150 pounds.

The *cable* is of 3-inch Manilla rope, 40 fathoms in length.

The *lashings* for both balks and side rails are of 1-inch Manilla rope, 18 feet in length, with a loop at one end.

The *tar bucket* is of the pattern issued by the Ordnance Department.

Carriages and their loads.—The carriages are of four descriptions: The ponton wagon (Plate III) differs from the chess wagon (Plate VI) only in being of heavier construction, in having longer side rails, and in the form of the stakes for securing the load. All important details are given on Plates IV and V. The tool wagon (Plate X) differs from that ordinarily used in the Quartermaster Department only in the form of the body. The forge is identical with that furnished by the Ordnance Department.

As mules are usually employed for the transportation of these trains, the ordinary mule harness of the Quartermaster Department is employed, but with this alteration: the traces are continuous, as in the artillery service. When horses are employed, the light artillery harness, with a slight change in the pole straps, will answer.

The *ponton wagon* (Plate III) is loaded by first placing 7 long balks between the side rails, and entering the dowels on the front bolster into the holes made in the balks for this purpose. Above this course of balks is placed the ponton, stern foremost—the stern rings about 15 inches in advance of the front axle. The ponton is secured by lashing its rings firmly to those of the carriage. The anchor is slung under the side rails; the cable coiled as far forward as possible in the ponton; the oars and boat hooks laid in the ponton, and the small articles stowed in the ponton locker. An axe is placed in the slings on the rear axle.

The *chess wagon* (Plates VI and VII) is loaded by placing a course of 30 chess on edge, with their lower notches resting on the middle and rear bolsters. The transoms are laid on the upper notches abutting against the stakes. A second course of 30 chess is then placed directly over the first. The binders are then hooked on and secured.

The ponton wagon is used for the transportation of the *trestle and abutments.* (Plate VI.) A course of 7 long balks is first placed as described above. The next course consists of 7 short balks and 2 abutment sills. The third, of a trestle cap

with the false legs thrust into the cavities in its top, and the legs lashed against it so as to prevent the false legs from falling out. The suspension chains pass through the rings on the cap, and are lashed to the rings of the carriage. The shoes are strung on the suspension chains; 2 coils of 3-inch rope are laid on this load, and lashed to the forward rings of the carriage.

The *tool wagon* (Plate X) is loaded by hanging the cross-cut saws on the middle partition, teeth up; placing the four boxes of carpenters' tools in the left rear compartment, with the handsaws between them and the sides of the wagon; placing the picks in the left middle compartment, with the hatchets on top; placing the pick handles, axes, and some of the short shovels in the left front compartment, and placing the long shovels, etc., in the right compartment.

Tabular summary of the reserve train.

Articles.	Number.	Weight.	Aggregate weight.	Remarks.
		Lbs.	*Lbs.*	
Ponton carriages	10	2,200.0	22,000	Each ponton carriage is drawn by 8 mules or 6 horses; each tool wagon and forge, by 6 mules or 4 horses. The load of the ponton wagon is 2,900 pounds; of the trestle wagon, 2,635 pounds; of the chess wagon, 2,280 pounds; of the tool wagon, 2,100 pounds; and of the forge, 1,166 pounds.
Chess carriages	4	1,750.0	7,000	
Tool wagon	1	1,700.0	1,700	
Forge	1	2,217.0	2,217	
Pontons	8	1,600.0	12,800	
Balk, long	70	130.0	9,100	
Balk, trestle	14	90.0	1,260	
Chess	240	38.0	9,120	
Trestles, complete	2	472.0	944	
Abutment sills	4	130.0	520	
Saddle transoms	4	38.0	152	
Saddle sills	2	125.0	250	
Anchors	8	150.0	1,200	
Oars	40	22.0	880	
Boat-hooks	16	5.0	80	
Scoop-shovels	8	5.0	40	
Scoops, small	16	2.0	32	
Pickets	12	7.0	84	
Rack-sticks	48	0.8	39	
Buckets, India-rubber	8	3.0	24	
Axes	8	5.5	44	
Hatchets	8	1.2	10	
Cables	8	60.0	480	
Lashings	160	0.5	80	
Three-inch rope coils, 120 fathoms each.	4	180.0	720	
Tar buckets	16	7.0	112	
Totals	.....	.....	70,888	

ADVANCE-GUARD EQUIPAGE.

Organization.—The trains of this equipage are composed of 4 ponton divisions, each of which consists of 8 ponton, 2 chess, and 2 trestle wagons.

The load of the *ponton wagon* (Plate IX) consists of 7 balks, 16 chess, 2 side frames, 1 cable, 1 anchor, and a ponton chest containing 1 ponton cover, 14 transoms, 5 paddles, 2 scoops, 2 mallets, 20 lashings, 2 boat-hooks, 1 scoop-shovel, and 8 rack sticks.

The *chess wagon* contains 50 chess and 2 spare ponton covers.

The *trestle wagon* (Plate IX) carries 14 balks, 1 trestle complete, 1 abutment sill, and 1 coil of 3-inch and 1 of 1-inch rope.

The *forge* is forge A of the Ordnance Department.

When necessary, this load may be reduced by transferring a part of the tools and coal to a forage wagon.

The ponton wagon carries all the material necessary for constructing a complete bay. The division may, therefore, be increased or diminished by one or more ponton wagons without disorganizing it. When a forced march is to be made, and it is desirable to lighten the loads, the chess may be removed from the ponton wagons, the rope from the trestle wagons, and the load of the chess wagons be reduced to 40 chess. The number of the latter wagons in this case mast be increased to 5.

The tool wagon is loaded with—

30 axes,
40 shovels,
4 spades,
15 picks,
20 hatchets,
4 broad-axes,
4 adzes,
2 crow-bars,
10 augers,
2 cross-cut saws,
4 handsaws,
10 tin lanterns,
1 monkey-wrench,
1 sledge,
1 grindstone,
1 coil wire,
1 coil 3-inch rope,
1 coil 1-inch rope,
30 lbs. iron, assorted,
Chalk and chalk-lines,
Spikes, 6 and 4-inch, 25 lbs. each,
100 lbs. 6, 8, 10, and 20 penny nails,
2 sets blocks and falls,
5 rolls canvas,
6 palms,
2 doz. sail needles,
1 coil spun yarn,
12 balls twine,
1 gross 1, 2, and 5 inch screws,
4 boxes of tools, similar to those of the reserve train.

If necessary, part of this load may be transferred to a forage wagon.

Bridge material.—The wood work, with the exception of the claws of the balks and the blocks in the trestle caps, is entirely of white pine.

The *ponton frame* (Plate VIII, Fig. 1) is composed of two side frames, of twelve narrow and of two wide transoms. The former are strengthened at the ends by iron straps, which are

countersunk and perfectly smooth; all the edges of the frame and transoms are well rounded to prevent chafing the canvas. The wide transoms are of 10-inch by 1½ inch plank, provided with tenons to fit the mortises in the frame. The narrow transoms are of 4-inch by 2½-inch scantling. The articles of each of the above classes should be made exactly alike, so that they may be interchanged. Two of the narrow transoms are provided with an iron mooring becket.

The frame when assembled is held together by a rope passed through the rings in the ends of the side frame, and tightened with a rack-stick, (Plate VIII, Fig. 2.)

The canvas ponton frame used during the latter part of the war by the army of the Cumberland, was made somewhat differently from the one which has just been described. The side frames were divided at the middle, the two parts being connected together by stout hinges placed on the inside. The upper hinge was attached by screws; the lower was riveted. A greater number of flooring pieces were used for the bottom of the boat, and a couple of ropes were run through them, the slack of which was used to tie them into bundles when the boats were dismantled. There were also some differences in the framing of the sides, and in the kind of transoms used to connect all the parts together. Plate XVI, Fig. 6, shows the hinged canvas ponton frame as modified by the experience derived from the use of the boats first built.

The object in adopting this form was to dispense with the necessity of special ponton wagons and trains. All the parts of the bridge, except the balks, could be carried without difficulty in the ordinary army wagon. Special wagons were required for the latter, but they were very quickly made by throwing off the body of an army wagon and lengthening the coupling. Under circumstances where it is essential to economize transportation by keeping all teams fully employed at all times, or where a bridge equipage is suddenly prepared and there is no time to procure the regular ponton wagons, the system just described may be used with advantage. Additional wagons can at any time be procured, or broken ones replaced, from the surplus or depot transportation. Single hinged boats for service on the prairies, can be carried without difficulty in the ordinary trains.

The only ponton train carried by the army of the Cumberland from Chattanooga to Atlanta, and thence to Savannah

and Washington, was composed of hinged canvas pontons, and it gave general satisfaction.

The *ponton cover* (Plate VIII, Fig. 3) is of 0000 cotton duck, double seamed, with the border double for 1½ inches in width. The clew-line eyelets are of metal.

The *short balks* (Plate VIII, Fig. 5) are 22 feet by 4½ inches by 4½ inches, with 20 feet 10 inches space between the cleats, which are similar in construction to those of the reserve train.

The *chess* (Plate VIII, Fig. 4) are 11 feet by 12 inches by 1½ inches, with notches 18 inches in length; in other respects similar to those of the reserve train.

The *anchor* is a kedge weighing 75 pounds.

The *paddle* is of the ordinary form, 8 feet long.

The *boat-hook* is of the usual construction, except that the points are blunted to prevent injuring the canvas; it is 8 feet long.

The *ponton box* (Plate IX) is 8 feet long, 2 feet 4 inches wide, and 18 inches deep; the lid is covered with canvas, which overlaps 3 inches all around. It has strong rope handles at each end.

The *cable* is of 3-inch Manilla rope, 30 fathoms long.

The *lashings* are of 1-inch rope, 18 feet in length, and looped at one end.

The *mallet* is the ordinary carpenter's mallet.

The *scoop-shovels* are of galvanized iron.

The *trestles*, *trestle balks*, *abutment sills*, *scoop-shovels*, *scoops*, *rack-sticks*, *pickets*, *buckets*, and *tar buckets* are the same as for the reserve train.

Carriages and their loads.—The ponton wagon (Plate IX) is identical with the chess wagon of the reserve train (Plate VI). It carries all the bridge material of the advance-guard train. The loads are arranged as follows:

To load with the *canvas ponton*, (Plate IX), 7 common balks are laid between the rails and on the right side, where they are secured by the front bolster dowels; on the left, 8 chess are placed on edge, with their notches resting on the middle and rear bolsters. The two side frames are laid over the balks, with their bottoms against the chess. The wagon transoms are laid in the upper notches of the chess, and abutting against the stakes. Eight more chess are laid directly over the first course. The ponton chess, containing the canvas cover, transoms, lashings, rack-sticks, scoops, scoop-shovel, paddles, boat-hooks, and mallets, is placed on top of the side frames and against the chess. The binders are hooked down; the side frames are lashed

by their rings, and the chest by its handles, to the rings of the wagon. The cable is coiled on the side frames and in front of the chest, where it is lashed. The anchor is slung under the side rails, and an axe on the rear axle.

The wagon, loaded with the *trestle*, (Plate IX,) has 7 short balks and 2 trestle balks in the first course; 5 trestle balks, 1 sill, and 1 trestle-cap in the second; and 1 coil of rope and 2 trestle-legs in the third course. The legs are lashed on top of the trestle; the small parts are packed as in the reserve train.

The wagon is loaded with *chess* by first placing a course of 30 chess as in the reserve train, (see Plate VI,) and on these a second course of 20 chess, 10 of which are lashed against the right and 10 against the left wagon stakes. The lashings pass through the wagon rings. A light box containing 2 spare canvas ponton covers is lashed in front of the chess, and resting on the front bolster.

The *tool wagon* is loaded as in the reserve train.

Tabular summary of the Advance-guard Train.

Articles.	Number.	Weight.	Aggregate weight.	Remarks.
		Lbs.	*Lbs.*	
Ponton carriages	12	1,750.0	21,000	Each of these carriages is drawn by 6 mules or 4 horses. The load of the canvas ponton wagon weighs 1,985 pounds; of the trestle wagon, 2,060 pounds; of the chess wagon, 1,856 pounds; of the tool wagon, 1,938 pounds; of the forge, 1,166 pounds.
Tool wagon	1	1,700.0	1,700	
Forge	1	2,217.0	2,217	
Pontons, complete	8	510.0	4,080	
Trestles, complete	2	472.0	944	
Abutment sills	2	130.0	260	
Balks, short	70	90.0	6,300	
Balks, trestle	14	90.0	1,260	
Chess	228	33.0	7,524	
Anchors	8	75.0	600	
Paddles	40	4.0	160	
Boat-hooks	16	3.5	56	
Scoop-shovels	8	5.0	40	
Scoops, small	16	2.0	32	
Pickets	8	7.0	56	
Rack-sticks	64	0.8	51	
Buckets, India-rubber	8	3.0	24	
Axes, (on rear axles of wagons)	8	5.5	44	
Mallets	16	3.0	48	
Ponton chest	8	150.0	1,200	
Cables	8	45.0	360	
Lashings	160	0.5	80	
Coils of 3-inch rope	4	180.0	720	
Tar bucket	14	7.0	98	
Totals	.....	.....	48,854	

PERSONNEL.

The number of pontoniers which should accompany a ponton train in the field may be determined in the following manner:

There will be required for the construction of a bridge, with the materiel of—

One division: 1 commissioned officer; 5 non-commissioned officers; 56 privates.

Two divisions: 1 commissioned officer; 7 non-commissioned officers; 68 privates.

Three divisions: 2 commissioned officers; 10 non-commissioned officers; 77 privates.

Four divisions: 3 commissioned officers; 12 non-commissioned officers; 117 privates.

If, therefore, the train is to remain united, one full company of engineer troops, as at present organized, will be sufficient. If the train is to be separated, each division operating by itself, at least two companies will be necessary—as a small detachment must always remain with the supply division. This is the minimum and does not include drivers. When the number of pontoniers is insufficient, the deficiency may be supplied by details from the line, in the proportion of thirty men for one division, or two combined, and seventy men when the train is not divided.

CHAPTER III.

BOAT MANŒUVRES.

The pontons of the reserve train are often used as bateaux in crossing rivers by force, and for embarking and disembarking the army and its stores; moreover, the construction of bridges by night over deep and rapid streams is a common occurrence in a campaign. A well-instructed pontonier must, therefore, be a good boatman. The following exercises, designed to impart this knowledge, are to be thoroughly taught and frequently practised, keeping in mind, especially in the school of the flotilla, that the chief object is to render the troops expert in handling the boats, and to accustom them to manœuvre without interference in restricted positions.

SCHOOL OF THE PONTONIER.

The object of this school is individual instruction in the use of the oars, paddles, and boot-hooks. It is to be carefully supervised by the commissioned officers of the company, who will pass, if practicable in skiffs, from ponton to ponton, and see that every part of the drill is properly taught.

The instructor (usually a non-commissioned officer) embarks his detachment, consisting of six privates, and pushes out into deep water; where, if the current be strong, he casts anchor. The boat is provided with 7 oars, preferably 14 feet long for this school, 3 boat-hooks, and 1 anchor and cable.

The instructor, placing himself in the stern, details each private in turn to practise with the oar, the rest being allowed to lean against the gunwales, paying close attention to the drill.

At the command ATTENTION, the pontonier inserts the row-lock in the socket, and then, facing aft, places himself in the middle of the ponton abreast with his row-lock, assuming the position of a soldier as prescribed in infantry tactics.

At the command UP OARS, he seizes his oar, and raises it briskly to the vertical in front of the center of his body, the handle resting on the bottom of the boat, and the blade athwartships. The hand next his row-lock grasps the oar at the height of the chest, elbow and wrist horizontal, the other steadies it at a point 12 inches lower.

At the command LET FALL, he steps off with one foot 18 inches perpendicularly toward the side opposite to his row-lock, and lowers his oar so that it touches the water before striking the gunwale; special attention is required that it does not fall upon the row-lock, into which it should be placed gently with the blade horizontal. He next slips one hand to the grip, and places the other on the oar 8 inches from it, the backs of both being up and the wrists lowered, and breaks to the rear 18 inches with the foot next to his row-lock.

At the command GIVE WAY TOGETHER, always given when the oar is at the final position indicated for LET FALL, (or at HOLD WATER, in which case the oar is at once brought to this position,) he raises his wrists and extends his arms, throwing the weight of the body well forward, drops the blade vertically into the water, throws his weight strongly backward upon the oar, disengages it from the water, and resumes his first position. These motions are repeated with regularity, taking care to make a long sweep, to keep the oar near the water, and to feather it by depressing the wrist after every emersion, until either WAY ENOUGH, or OARS, is ordered. The instructor will insist that the oar shall be moved by the weight of the body, and not by the force of the arms.

At the command WAY ENOUGH, which must always be given when the *oar is in the water*, he gives one stroke, raises his oar to a vertical position, and lays it easily and without noise into the ponton, the blade toward the bow.

At the command OARS, which must always be given when the *oar is in the water*, he gives one stroke if rowing, and resumes the final position indicated for LET FALL; at the position HOLD WATER, the stroke is omitted.

At the command HOLD WATER, always given when the oar is in the final position indicated for LET FALL, he raises the grip so as to engage the blade in the water, and holds the oar firmly at right angles to the boat, blade vertical. The object, of course, is to check the headway when in motion.

At the command STERN ALL, always given when the oar is at HOLD WATER, or at the final position indicated for LET FALL, he reverses the operation of rowing as described under GIVE WAY TOGETHER, and by pushing vigorously against the oar when immersed, gives the boat a motion astern. The operation ceases at the commands WAY ENOUGH or OARS, which are executed as described above.

The command SCULL is always given when the oar is in the final position indicated for LET FALL. It is first taught by placing the pontonier at the row-lock in the stern, which he faces. The oar is nearly balanced in a horizontal position in the row-lock, the blade horizontal, and is held by clasping the grip with both hands, the backs up and the right hand next the body. The feet are placed 30 inches apart, on a line parallel to the stern, and at a convenient distance from it. At the command SCULL, the weight is thrown on the right leg, and the blade, after being carried to the left, is immersed, giving it, at the same time, an inclination toward the right by depressing the right elbow. The weight is now strongly thrown on the oar, the body bending toward the left. The blade is turned at the same time in the water, by varying the position of the elbows, so that at the end of the stroke it inclines toward the left ready for the reverse stroke—which is immediately given without letting the oar emerge from the water. This oblique passage of the oar through the water, to the right and left alternately, forces the boat forward; and by varying the amount of pressure in the alternate strokes, it may be turned toward either side. To scull a boat skillfully requires considerable practice, which must first be acquired at the stern row-lock. Afterward, the pontonier is required to execute the same movements at the side row-lock, placing himself in the most convenient position permitted by the length of the oar in use. The command WAY ENOUGH, or OARS, terminates the motions.

The command TRAIL is given only when the oar is in the final position indicated for LET FALL, and when it is attached by a trail-line to the gunwale. The command is obeyed by unshipping the oar from the row-lock and letting it trail in the water alongside. The command SHIP restores the oar to its former position.

The command UNSHIP is given only when the oar is in the final position indicated for LET FALL, and is executed by removing the oar from the row-lock and letting it trail alongside, held by the hand next the gunwale. This position is used whenever it is necessary to prevent fouling the oars suddenly, as in shooting a bridge. The command SHIP restores the oar to its former position.

The command BOAT YOUR OARS may be given when the oar is in the final position indicated for LET FALL, or at UP OARS. The pontonier raises his oar to the vertical, if not already there,

lays it gently on the bottom of the boat, blade toward the bow, and takes the position of ATTENTION.

The command REST may be given when the pontonier is at ATTENTION or at TRAIL OARS. He is no longer required to preserve silence or his position.

The use of the boat-hook is too varied to be reduced to a manual. It is held by both hands, and is used for pushing the boat in shallow water for holding it fast alongside another boat, or by the bank, for recovering articles lost overboard, etc. It is taken from the bottom of the boat at the command HANDLE BOAT-HOOKS, and is laid down again, prongs toward the bow, at the command LAY IN BOAT-HOOKS.

Pontoniers are also to be practised in the use of the paddle belonging to the advance guard train—which may easily be taught in the wooden ponton. A manual for it is deemed unnecessary.

SCHOOL OF THE BOAT.

The object of this school is the instruction of the pontoniers in the management of the single boat. It is not to be taught until all of the crew are thoroughly familiar with the use of the oar and boat-hook, as taught in the preceding school. The exercise will be conducted under the close supervision of commissioned officers, who will move from boat to boat and see that all the commands are thoroughly understood and properly executed. When practicable, it will be well at first to use 14-foot oars, replacing them by the regular 18-foot oars as soon as the crew is sufficiently drilled to render the change advisable.

To embark.—The instructor, a noncommissioned officer, provides his detachment with 7 oars and 3 boat-hooks, forms it in single rank with the best oarsmen on the right, files it left in front into the ponton (supposed to be in the water moored to the bank by the stern), and deposits the oars in the bottom of the boat, six of them with the blades toward the bow and the seventh reversed. The boat-hooks are placed outside the oars, prongs toward the bow. The cable is coiled in the bow, with the lower end made fast to the starboard mooring post and with the other bent to the anchor by the knots shown on Plate XII. The anchor is placed with its arms projecting vertically over the bow and its stock resting on the gunwales aft of the mooring-post.

The command ATTENTION is executed as directed in the

school of the pontonier, the crew arranging themselves in the order in which they were formed on shore, the right file (stroke oar) taking the after starboard row-lock, and the others alternating, the even numbers being on the port side. The instructor then directs one or two of the men next the stern to step on shore, remove the lashings, and prepare to push the ponton from the bank.

The command UP OARS is executed as prescribed in the school of the pontonier; the instructor takes the reversed oar himself, and drawing it aft horizontally, puts the blade over the side or stern, and prepares to use it in pushing off from the bank.

At the command SHOVE OFF, the men on shore, aided by the instructor and, if necessary, by others of the crew with their oars, disengage the ponton from the bank, and jump in. All the oarsmen then assume the position of UP OARS, and the instructor places his oar in the stern row-lock in readiness to direct the course of the boat.

The command LET FALL is then executed as prescribed in the school of the pontonier.

Simple exercises.—The crew is next drilled to execute in unison the following movements as prescribed in the school of the pontonier, the after starboard oarsman giving the time: GIVE WAY TOGETHER! WAY ENOUGH! UP OARS! LET FALL! OARS! HOLD WATER! STERN ALL! TRAIL! UNSHIP! SHIP! BOAT YOUR OARS! REST!

In order to secure a simultaneous and very prompt execution of these movements, the following cautionary commands may be used: STAND BY TO GIVE WAY TOGETHER! STAND BY TO LAY ON YOUR OARS! STAND BY TO STERN ALL!

In practising these exercises, the instructor will not rest satisfied until the entire crew can execute them simultaneously and with life. It is better to require vigorous exertion, interspersed with frequent rests, than to induce a habit of sluggish and irregular execution by over-fatiguing the men. It should be added, that the instructor need not shift his position when the men are backing, as he can readily steer from the stern. Indeed, the boat is moved in this direction with nearly the same facility as to the front.

When the crew is well drilled in the foregoing simple exercises, the following more complicated movements will be taught:

To turn the boat rapidly.—The men being at the final position indicated for LET FALL, the instructor commands, GIVE WAY STARBOARD (or PORT)! BACK PORT (or STARBOARD)! Pulling and backing oars keep stroke with the after oar of their own side. Desiring to cease turning round, the instructor commands, GIVE WAY TOGETHER! at which the backing oars take the direct stroke. Assisting with his own oar, the instructor can turn the ponton with great rapidity and in a very small space by this method.

To move sideways.—It is sometimes desirable to move the ponton a short distance to starboard or to port without advancing or backing. This is effected in the following manner: To move to starboard, the instructor directs the bow oarsman to shift his oar into the bow row-lock, moving the anchor a little if necessary, and to face to starboard. The crew being at the final position indicated for LET FALL, he then orders, PORT PREPARE TO SCULL! and facing himself to starboard prepares to back with his oar. All being in position he commands, BACK AND SCULL! The port oarsmen (without attempting to keep stroke) then scull, each through his own row-lock, and the instructor and the bow oarsman back steadily so as to preserve the boat parallel to its former position. The desired movement having been effected, the instructor orders, OARS! when all take their designated positions, the bow oarsman shifting to his usual place.

The movement to port is executed in a similar manner by the commands: 1. STARBOARD PREPARE TO SCULL! 2. BACK AND SCULL!

To cast anchor.—The ponton is first headed to the current and its way checked. At the command PREPARE TO CAST ANCHOR, the starboard and port bow oarsmen boat their oars; the former unships the bow row-lock (if in the socket) and sees that the cable is clear, while the latter seizes the stock with both hands, each one foot from the shank, and stands ready to cast it overboard. At the command CAST ANCHOR, he tips it into the water and assists the starboard-bow oarsman in paying out the cable. When the ponton has dropped astern (or been backed) about five times the depth of the water, they take a single turn around the port mooring post and hold strongly upon the cable to make the flukes take hold of the bottom. When this is accomplished, they gradually pay out about as much more rope, and then secure the cable to the port mooring

post by the knot shown on Plate XII. In deep water a less relative length of cable will suffice. The instructor then commands, BOAT YOUR OARS!

To weigh anchor.—The instructor brings the crew to the position of ATTENTION, and commands: 1. PREPARE TO WEIGH ANCHOR! 2. UP OARS! 3. LET FALL! At the first command the port-bow oarsman loosens the cable from the port mooring post, and, aided by the starboard-bow oarsman, passes it over the middle of the bow; they then stand ready to haul in. The remaining pontoniers obey the second and third commands, as given. The instructor then commands, GIVE WAY TOGETHER! and slowly moves the ponton toward the anchor, the bow oarsmen taking in the slack of the cable and neatly coiling it away in the bow. When the cable becomes vertical the headway of the boat is checked, and the two men pulling vigorously raise the anchor to the bow, where it is held by the starboard-bow oarsman, while the port-bow oarsman seizes the stock with both hands, and, aided by the other, lifts it to its position already described. They then resume their oars and take the stroke.

To debark.—On approaching the landing place, the ponton being headed in the right direction, the instructor commands, IN BOWS! At this command the two bow oarsmen give one stroke, and boating their oars as directed in the school of the pontonier, handle the boat-hooks and stand ready to assist in the landing. When sufficient headway has been gained, the instructor commands, WAY ENOUGH! which is executed as prescribed; the stroke oarsman then handles the remaining boat-hook to assist in the landing. The instructor, with the steering oar, then brings the ponton to the bank in the most convenient manner, causes it to be properly secured, unships the row-locks, and lands his men in a way similar to that prescribed for embarking them.

To salute.—When passing a boat containing a commissioned officer of superior rank to any in the ponton, the chief brings his crew to the position of OARS. The salute is acknowledged in the same way.

SCHOOL OF THE FLOTILLA.

A flotilla generally consists of one ponton division of eight boats, but it may comprise any number of boats greater than one. It is commanded by a commissioned officer, usually a

captain, who, if practicable, should make use of a light skiff with a picked crew, in order to enable him to move rapidly to any point where his presence may be required. Lieutenants, in the pontons, act as file closers to promptly rectify errors and to prevent confusion.

All commands of the captain are to be repeated in a loud tone by the lieutenants, and if necessary by the chiefs of pontons. Commands of caution are to be separated from those of execution by a sufficient interval to allow the chiefs of pontons to add the requisite directions to their pontoniers. Commands of execution are to be obeyed as soon as heard.

Inversions are ignored. The front is always toward the bows of the pontons; hence FORWARD always calls for a direct stroke, and IN RETREAT, for a back stroke.

The tactical unit is the single boat. In line or echelon the pontons are numbered from the actual right; in column of single boats, from the front; and in a column of sections, (several boats abreast), from the right and front. Thus in a column of three boats abreast, No. 1 is on the right of the leading rank, No. 2 is on the left of No. 1, No. 3 is on the left of No. 2, No. 4 is behind No. 1, etc.

Sections, when formed, are numbered in a similar manner. They are commanded by the senior lieutenant or sergeant in them, who gives the orders prescribed for the chiefs of pontons in the formations by boat, with any needful directions.

The usual interval between boats abreast is 20 yards, and between boats in file, 12 yards. These distances may be changed by the captain, but they must not be reduced below 12 yards and 4 yards, respectively. In a very rapid current, they should be considerably increased.

Any ponton may be designated as the guide, but in wheeling the guide is always on the wheeling flank.

To embark.—The company is formed in single rank, and divided into detachments consisting of one noncommissioned officer, called chief of ponton, and six privates, the best oarsmen being on the right. The chiefs of pontons are posted two paces in front of their men, in line and in column of detachments, and abreast of the leading man when marching by the flank. Lieutenants take their posts as prescribed for field officers in infantry battalion drill.

The company is marched preferably in column of detachments to the depot, where each detachment is supplied with 7 oars

and 3 boat hooks, which are carried by the privates on the shoulder, the blades well up. The march is then directed to the shore, where the pontons are supposed to be in the water, about twenty yards apart and moored by their sterns perpendicularly to and touching the bank.

The column approaches by the most convenient flank, with the guide on the side of the boats. The captain orders: DETACHMENTS OPPOSITE YOUR PONTONS! when each detachment is halted successively and wheeled into line facing his boat, by its chief—beginning at the rear detachment, which halts opposite the first boat. The captain then orders: 1. DETACHMENTS TO YOUR POSTS! 2. MARCH! At the first command each chief of ponton orders: 1. DETACHMENT, RIGHT (or LEFT) FACE! 2. COLUMN LEFT (or RIGHT)! so as to cause the original left to lead off, and repeats the command MARCH of the captain. The detachments file into the pontons, and each chief orders: ATTENTION! and UP OARS! as prescribed in the school of the boat.

Seeing every boat in readiness, the captain orders: SHOVE OFF! which is executed as prescribed in the school of the boat. The captain then orders: 1. PONTON NO.—THE GUIDE! 2. FLOTILLA FORWARD! 3. MARCH! At the second command, each chief of ponton orders: LET FALL! and at the third command: GIVE WAY TOGETHER! The chief of the guiding ponton directs his boat perpendicularly to the shore at a moderate speed. The other chiefs, particularly those of the adjacent pontons, are careful to preserve the intervals and the alignment. The captain then embarks in his skiff, and follows up the movement.

If the pontons are not in position when the column approaches, it is halted, the oars and boat-hooks are piled. (those of each detachment separately,) and the boats are brought into position, as indicated. At the command FALL IN! the detachments reform, resume their oars and boat-hooks, and the drill proceeds as before.

If the shore does not favor the formation of a long line of boats, they are moored near together, and the flotilla advances in column, from the right or left, in the manner soon to be described.

Having gained a sufficient distance from the shore, the captain proceeds to manœuvre the flotilla. Three formations are recognized—in line, in echelon, and in column. For convenience of reference, all the movements permitted from each of these

formations will be described in turn as classified in the following table:

Evolutions of a flotilla

In line.	In echelon.	In column.
To halt.	To reform line.	To halt.
To dress.	To halt.	To advance.
To advance.	To advance.	To retreat.
To retreat.	To retreat.	To oblique.
To oblique.	To oblique.	To change direction.
To wheel.		To extend intervals.
To extend intervals.		To close intervals.
To close intervals.		To form line to either flank.
To form column to front.		To form line to front.
To form column to rear.		To form line to rear.
To form column to either flank.		
To form echelon to the front.		
To form echelon to the rear.		

To these should be added the anchorage and debarkation, which may be executed from any formation.

In line, to halt.—Whether advancing or retreating, the captain commands: 1. FLOTILLA! 2. HALT! At the first command the chiefs of pontons order: STAND BY TO LAY ON YOUR OARS! At the second command they order: OARS! HOLD WATER! followed by OARS! when the headway is checked.

In line halted, to dress.—The captain commands: 1. ON PONTONS NOS.— AND—! 2. DRESS! The two designated pontons, which must be adjacent, remain as steadily as possible in position, while the others place themselves on the line.

In line, to advance.—This may be done whether halted or in retreat. The commands of the captain are: 1. PONTON NO.— THE GUIDE! 2. FLOTILLA FORWARD! 3. MARCH! They are executed as already described for embarking, omitting the command LET FALL, if not required. If in retreat, each chief orders: 1. OARS! 2. HOLD WATER! at the second command.

In line, to retreat.—Whether advancing or at a halt, the captain commands: 1. PONTON NO.—THE GUIDE! 2. FLOTILLA IN RETREAT! 3. MARCH! At the second command, if advancing, each chief orders: 1. OARS! 2. HOLD WATER! If at a halt, he brings his crew to the position of OARS. At the third command he orders, STERN ALL! which is executed as prescribed in the school of the boat.

In line, to oblique.—Authorized only when advancing or re-

treating. If the former, the captain orders: 1. FLOTILLA RIGHT (or LEFT) OBLIQUE! 2. MARCH! At the first command each chief orders: OARS! at the second command he adds, GIVE WAY PORT (or STARBOARD)! BACK STARBOARD (or PORT)! When the boat has changed its direction 45°, he commands: GIVE WAY TOGETHER! and directs his boat so as to preserve his proper interval from the guide, on a front parallel to the original alignment.

To resume the direct march, the captain orders: 1. FLOTILLA FORWARD! 2. MARCH! The chiefs of pontons order: OARS! and GIVE WAY STARBOARD (or PORT)! BACK PORT (or STARBOARD)! and GIVE WAY TOGETHER! as before.

If retreating, similar commands are given, substituting IN RETREAT for FORWARD, and STERN ALL for GIVE WAY TOGETHER.

In line, to wheel.—Authorized only when advancing or retreating. If the guide is not already on the wheeling flank, the captain changes it there, and then orders: 1. FLOTILLA RIGHT (or LEFT) WHEEL! 2. MARCH! At the first command the chiefs of pontons near the pivot order: STAND BY TO LAY ON YOUR OARS! At the second command they order: OARS! and if necessary, HOLD WATER! Each chief then steers and cautions his men in such a way as to execute a wheel as nearly as possible on a fixed pivot—the pontons near the centre being careful to rather fall a little behind than to advance beyond their position.

To resume the direct march the captain orders: 1. FLOTILLA FORWARD (or IN RETREAT)! 2. MARCH! At the first command the chiefs of pontons near the pivot order: STAND BY TO GIVE WAY TOGETHER (or to STERN ALL)! and at the second command: GIVE WAY TOGETHER (or STERN ALL)!

In line, to extend intervals.—Authorized whether advancing, retreating, or at a halt. The captain commands: 1. ON PONTON NO. — TO — YARDS EXTEND INTERVALS! 2. MARCH! If advancing or retreating, the chiefs of pontons order: OARS! at the first command, and give the orders prescribed for obliquing toward the proper flank, at the second—resuming successively the direct march as the intervals are gained.

If at a halt, the chiefs of pontons execute the movement prescribed for moving sideways in the school of the boat, halting when the intervals are gained.

In line, to close intervals.—Authorized whether advancing, retreating, or at a halt. The captain commands: 1. ON PON-

TON NO. — TO — YARDS CLOSE INTERVALS! 2. MARCH! This movement is executed upon the same principles as the last, by gaining distance toward the opposite flank.

In line, to form column to the front.—Authorized whether advancing or at a halt. The captain orders: 1. BY PONTON FROM THE RIGHT (or LEFT) FRONT INTO COLUMN! 2. MARCH! If advancing, the chief of the right (or left) ponton cautions his men to continue rowing slowly; the others give the order: STAND BY TO LAY ON YOUR OARS! At the second command they add: OARS! As soon as the designated ponton has passed the next in line, the chief of the latter orders, GIVE WAY TOGETHER! and steers obliquely into position behind the first, on a course making an angle of about 45° with the former direction. The other pontons successively follow the movement, so as to enter the column on parallel lines and at their proper intervals.

If at a halt, the movement is executed on similar principles, the chiefs of pontons giving in succession the commands: STAND BY TO GIVE WAY TOGETHER! GIVE WAY TOGETHER! so as to form the column as before.

If the captain desires to form a column of sections, each consisting of several pontons (say three) abreast, he orders: 1. BY THREE PONTONS FROM THE RIGHT (or LEFT) FRONT INTO COLUMN! 2. MARCH! 3. GUIDE LEFT (or RIGHT)! The movement is executed upon the same principles as the foregoing, the boats of each section acting together under orders from the lieutenant, or chief of ponton senior in rank.

In line, to form column to the rear.—Authorized whether retreating or at a halt. Executed by the same commands and upon the same principles as the foregoing, substituting TO THE REAR for FRONT, and STERN ALL for GIVE WAY TOGETHER.

In line, to form column toward either flank.—Authorized whether advancing, retreating, or at a halt. The captain commands: 1. BY PONTON RIGHT (or LEFT) WHEEL! 2. MARCH! 3. FORWARD! (or if retreating IN RETREAT!) 4. MARCH!

If advancing, each chief of ponton orders: STARBOARD (or PORT) STAND BY TO LAY ON YOUR OARS! at the first command. At the second he orders: STARBOARD (or PORT) OARS! HOLD WATER! At the third command he directs: STAND BY TO GIVE WAY TOGETHER! And at the fourth he orders: GIVE WAY TOGETHER!

If retreating, the chiefs of pontons give the same commands,

substituting PORT for STARBOARD and STERN ALL for GIVE WAY TOGETHER.

If at a halt, the commands of the chiefs of pontons are: STAND BY TO GIVE WAY PORT (or STARBOARD), BACK STARBOARD (or PORT)! GIVE WAY PORT (or STARBOARD), BACK STARBOARD (or PORT)! STAND BY TO GIVE WAY TOGETHER! GIVE WAY TOGETHER!

If the captain wishes to form a column of sections composed of, say, three pontons, he gives the same commands, substituting THREE PONTONS for PONTON; and adds the command GUIDE LEFT (or RIGHT)! when the movement is completed. The wheel is executed by the commands and principles prescribed for wheeling by flotilla.

In line, to form echelon to the front.—Authorized whether advancing or at a halt. The captain commands: 1. BY PONTON (or — PONTONS) FROM THE RIGHT (or LEFT)! 2. AT — YARDS! 3. FRONT INTO ECHELON! 4. MARCH! At the third command the chief of the designated pontons cautions his section to continue moving if advancing, and orders: STAND BY TO GIVE WAY TOGETHER! if at a halt. The other chiefs command: STAND BY TO LAY ON YOUR OARS! if advancing, and caution their sections to remain steady, if at a halt. At the fourth command the designated pontons advance, followed successively at the indicated distance by the remaining sections, all preserving their proper lateral intervals from the leading boat. The chief object of this manœuvre is to enable the line to conveniently regain these lateral intervals when, owing to the velocity of the current or to want of skill, the boats have become crowded.

In line, to form echelon to the rear.—Authorized whether retreating or at a halt. The line may retire in echelon by means and commands similar to those of the movement last described, substituting IN RETREAT for FRONT, and STERN ALL for GIVE WAY TOGETHER.

In echelon, to reform the line.—Authorized whether advancing, retreating, or at a halt. The captain commands: 1. ECHELON INTO LINE ON LEADING PONTON (or SECTION)! 2. MARCH!

At the first command the chief of the leading ponton or section, if advancing or retreating, orders: STAND BY TO LAY ON YOUR OARS! The others caution their men to continue rowing. At the second command the leading chief orders: OARS! HOLD

WATER! followed by OARS! when his headway is checked. The other pontons or sections successively halt on the line by the same commands.

If at a halt, the leading chief cautions his men to lay on their oars, and the others order: STAND BY TO GIVE WAY TOGETHER (or TO STERN ALL)! At the second command they order: GIVE WAY TOGETHER (or STERN ALL)! and form line as before.

In echelon, to halt, to advance, to retreat, and to oblique.—The same commands and principles of execution are followed as in line, except that the guide is always on the leading echelon.

In column, to halt, to advance, to retreat, and to oblique.—The same commands and methods of execution are followed as in line, except that the flotilla is called COLUMN, and that when the right is in front the guide is left, and *vice versa*.

In column, to change direction.—Authorized only when advancing or retreating. The captain commands: 1. COLUMN RIGHT (or LEFT)! 2. MARCH! The chief of the leading ponton or section at once executes a wheel by using the steering oar, and, if necessary, by cautioning the oarsmen toward the pivot to pull gently. The radius of the wheel must be large enough to leave the wheeling point clear for the boats behind. Each boat or section executes the same movement upon arriving at the same ground. The guide is always toward the wheeling flank.

In column, to extend intervals.—Authorized whether advancing, retreating, or at a halt. The captain orders: 1. BY HEAD (or REAR) OF COLUMN TAKE—YARDS INTERVALS! 2. MARCH!

If at a halt, the chief of the designated boat or section orders: STAND BY TO GIVE WAY TOGETHER (or TO STERN ALL!) and at the second command he orders: GIVE WAY TOGETHER (or STERN ALL)! These commands are repeated successively by the chiefs of the boats or sections in rear, in time to secure the designated intervals.

If in motion, intervals must be taken only from the head of column. The chiefs of all pontons behind the leading boat or section order at the first command: STAND BY TO LAY ON YOUR OARS! at the second command they order: OARS! and resume the march successively as the designated intervals are gained.

In column, to close intervals.—Authorized whether advancing, retreating, or at a halt—in the latter case only on the head of column. The captain orders: 1. COLUMN CLOSE TO—YARDS INTERVALS! 2. MARCH! The movement is executed by the same

commands and principles as the last, the boat in front halting or remaining at a halt, and those in rear moving up together and halting successively in position, at the command of their chiefs.

In column to form line toward either flank.—Authorized whether advancing, retreating, or at halt.—The captain orders: 1. RIGHT (or LEFT) INTO LINE WHEEL! 2. MARCH! 3. FORWARD (or IN RETREAT)! 4. MARCH! 5. PONTON NO.—THE GUIDE! The movement is executed by the commands and principles prescribed for wheeling from line into column, the pivots wheeling as nearly as possible on their own ground.

In column to form line to the front.—Authorized only when advancing or at a halt. The commands of the captain are: 1. RIGHT (or LEFT) FRONT INTO LINE! 2. MARCH! The leading ponton or section, by command of its chief, moves forward sufficiently to give the one following room to oblique into position, and then halts. The chiefs of the other pontons or sections give the commands prescribed for obliquing into line, move opposite to their positions, advance to the line, and halt—dressing upon the leading ponton or section.

In column, to form line to the rear.—Authorized only when retreating or at a halt. The commands of the captain are: 1. RIGHT (or LEFT) IN RETREAT INTO LINE! 2. MARCH! The movement is executed upon the same principles as the last.

To anchor the flotilla.—The flotilla may be anchored, whether in line, in echelon, or in column; whether at a halt or in motion; and whatever be the direction of the current—but, except in emergencies, the march should be directed up or down stream before giving the command. The orders of the captain are: 1. PREPARE TO CAST ANCHOR! 2. CAST ANCHOR! 3. BOAT YOUR OARS! 4. REST! They are executed as prescribed in the school of the boat—the chiefs of pontons being careful to make fast their cables at such a length as to preserve their proper positions respecting the guide.

To weigh anchor.—The commands of the captain are: 1. ATTENTION! 2. PREPARE TO WEIGH ANCHOR! 3. FLOTILLA FORWARD (or IN RETREAT)! 4. MARCH! 5. PONTON NO. — THE GUIDE! At the second command, each chief of ponton, after cautioning the two bow oarsmen to handle the cable, orders: UP OARS! At the third command he orders: LET FALL! and at the fourth command: GIVE WAY TOGETHER (or STERN ALL)! The anchor is weighed as prescribed in the

school of the boat. The fifth command of the captain is not given until he sees the anchor up in the ponton which he designates; this boat moves very slowly forward until all the anchors are weighed and the pontons are in line.

To debark.—This movement may be executed from line, from echelon, or from column, preferably when in retreat. The captain, upon approaching the shore, makes the up-stream ponton the guide, and orders: 1. PREPARE TO DEBARK AT — YARDS INTERVALS! 2. DEBARK WITH (or WITHOUT) OARS AND BOAT-HOOKS! At the first command the guiding ponton is beached, and secured as prescribed in the school of the boat; the others, obliquing if necessary, gain the indicated interval and execute the same movement. At the second command, which is not given until all the boats are secured, the chiefs of pontons file their men out, equipped as indicated, and form them in single rank, facing their respective boats. The captain then orders: 1. BY DETACHMENT RIGHT (or LEFT) WHEEL! 2. MARCH! 3. TO WHEELING DISTANCE CLOSE COLUMN! 4. MARCH! 5. GUIDE LEFT (or RIGHT)!

The company having been thus reformed in column of detachments, may be marched to the depot to store the oars and boat-hooks; it is then conducted to the usual place of formation, to be dismissed.

FERRIAGE OF TROOPS.

The passage of rivers is usually effected by ordinary military bridges, or by forming the boats into movable rafts, held in position by ropes. There are times, however, when the enemy, by occupying with a thin line of skirmishers the opposite bank at the desired point of crossing, can effectually prevent the construction of either of these means of passage until his reserves have had time to come up. In such cases it is necessary to effect a passage by force by suddenly ferrying a body of picked men, infantry or cavalry, across the stream to drive away the skirmish line, while the pontoniers are making the bridge for the main body; for it must be assumed as definitely settled by experience in the late war that it is impossible to construct a regular bridge under the fire of sharpshooters, even when favored by fog or night. The bridge may be commenced, but it can not be completed, no matter what be the efforts of our artillery and infantry, provided the enemy is supplied with the modern rifled musket, is covered by rifle-pits, and is possessed of ordinary courage.

The gathering of pontons at any spot will cause it to be carefully watched. It is therefore very advantageous, in forcing a passage, to transport the boats by hand a sufficient distance to prevent the sound of wagons being heard.

This was done at Fredericksburg during the late war, where twenty pontons were transported nearly a mile in three hours, and launched without discovery. Thirty infantry soldiers were required for each boat. They turned it upside down, and carried it on poles about ten feet long, which were placed under and across the gunwales. These poles were supported by the hands, the arms extended at full length. At some preparatory experiments it was found that twenty pontoniers could carry a ponton in this manner two or three hundred yards without resting, the weight supported by each man averaging about eighty pounds. In smooth grass land, or through mud, a ponton may be easily moved by drag ropes, using either men or horses. For long distances a temporary sled, made of two stout planks with suitable cross-pieces, should be employed. A ponton may be dragged many miles in this manner. Canvas boats may readily be carried on the shoulder long distances by ten men, but the difficulty of rowing renders them far less useful for forcing the passage of a river than the wooden boats.

The boats having been launched, are floored with chess and moored by the stern to the bank, if practicable not less than thirty yards apart, and the pontoniers take their prescribed positions. If the river is narrow, or if the requisite number of boats cannot be secured, the two oarsmen in the middle are placed, one in the bow and one in the stern, to act as a reserve in case of casualties. Their oars are left in the bottom of the ponton. If the available boats will transport the desired number of men, six oars should be used in each, and an extra detail of two pontoniers must be supplied as a reserve. Two extra oars should also be provided in this case to replace any shattered by bullets. A detail of pontoniers, or of troops of the line, is made to shove off; they take post in the water by the side of the pontons, and remain behind when the start is made. The flotilla is now ready for the troops to embark.

Infantry.—The men should be formed in line of battle and told off into squads, one for each ponton. When the current is gentle and six oars are used, squads of forty men, fully equipped with knapsacks, blankets, etc., may be safely trans-

ported. With four oars it is possible, but not advisable, to carry squads of fifty men.* The squads must include the proper complement of commissioned and noncommissioned officers, who ought always to accompany their men. The strictest orders should be given to preserve perfect silence, to remain steady in position no matter how much the boat may rock, and under no circumstances to open fire from the river.

The canvas ponton with six paddles will carry a squad of twenty men fully equipped; they should be made to sit or kneel down in the bottom of the boat, which is floored with eight chess.

The squads are marched silently by the flank to their respective pontons, each conducted by a pontonier. They enter by the stern, and advance as near the bow oarsman as the sweep of his oar will permit. The outer files sit on the gunwales, alternating from side to side; the space between them is filled by the others who, in case of rocking, steady themselves by grasping the arms of those sitting down. When six oars are used, the pontoniers in the middle must not be crowded.

If the boat grounds when the men are filing in, the detail on shore push it further from the bank, and the remainder of the squad enter by wading.

As soon as the chief of ponton sees that the squad for his boat is all on board, he brings the crew quietly to the position of OARS.

As soon as the chief of flotilla ascertains that all is in readiness, he gives the signal to advance, usually embarking himself in the up stream ponton. This boat is always the guide, and every exertion is made by its chief to cross the stream perpendicularly to its length without attempting to struggle with the current, unless the nature of the opposite bank renders it necessary to do this in order to reach a good landing place. The proper intervals are carefully preserved by the other boats; if any crowding takes place, the boat most annoyed drops a short distance behind.

If a boat grounds in the passage, the chief of ponton causes some or all of his pontoniers to bring their oars to the position of OARS, to transfer them to the nearest infantry soldiers, and to jump overboard and endeavor to disengage the ponton. If no further progress can be made, he causes some of them to

* On the occasion above cited, this number was actually ferried over the Rappahannock at Fredericksburg in a strong current, without accident.

wade toward the opposite shore; if the water is found to be sufficiently shallow, the infantry disembark. This is always done as soon as the boat touches the shore, the men passing over the bow. As fast as unloaded, the chief of flotilla causes his boats to STERN ALL, and to go back for another detachment without turning the pontons about.

Cavalry.—The pontons are prepared as if for the ferriage of infantry, except that four oarsmen only are required, and the flooring of chess is unnecessary.

If the current is gentle, and is to be crossed *perpendicularly*, six horses may be taken at a trip. The cavalry-men, with a commissioned officer or sergeant in charge, embark. Their equipments are placed in the ponton, and the men take post, three on each side, leading their horses by the bridles. The boat is pushed off by men in the water at the stern, and is conducted straight across the current, the horses swimming by the sides. The cavalrymen are instructed to hold their horses' heads well up, supporting them both with the bridle and by the hand. If possible, a landing place is selected where the bank slopes gently to the water. As soon as the horses strike bottom they are led on shore successively, beginning with the one next the bow. If the shore is bluff, a landing place must be prepared beforehand by digging.

In a very strong current, particularly where it is necessary to contend with it in order to reach the desired landing, only three horses can be taken. They are put on the down-stream side, lest they be drawn under the boat.

FERRIAGE OF MATERIALS.

Army supplies.—Pontons are well adapted for landing the supplies of the army from shipping, when time is lacking to make the requisite wharves. The boats are lined with chess and are loaded by falls from the yards. Six tons may thus be carried at a trip in smooth water.

Guns.—Field guns and, if necessary, siege guns, may be landed in like manner in still water.

When there is a rolling surf on the beach, a field gun may be made fast across the gunwales on skids, and be rolled over the stern into the water near the shore, having a hawser securely attached to it. One hundred men will haul up a light 12-pounder gun upon an ordinary sand beach in this man-

ner. To conduct the ponton, a warp line should be laid from the nearest vessel to the beach, and the boat should be hauled along it and held in position just outside the surf while the gun is rolled over. Unless the water is tolerably smooth, this operation is impossible; it is difficult under any circumstances. With a large navy launch, three 30-pounder Parrott guns were successfully landed in this manner on an exposed ocean beach at the taking of Fort Fisher in January, 1865, when a considerable swell was running. The time occupied averaged about thirty minutes per gun. A ponton would probably have lacked the requisite stiffness.

Ponton trains.—It is sometimes desirable to move the ponton trains by water in order to avoid a difficult land march. In such cases, they are rafted in the following manner:

Each ponton is loaded with twenty chess and seven balks, the latter uppermost. Partial rafts are then constructed by placing four pontons side by side; two balks are laid across their gunwales, one over the front, and the other over the rear, lashing ring, and secured firmly to these rings The partial raft which is to be attached to the tow-line of the steamer, has a balk lashed to and in rear of its bow mooring posts; to this the tow-line is attached. The remaining rafts are brought up in succession; each is attached by passing lines around its interior bow mooring posts, and the interior stern mooring posts of the raft preceding. As a precaution against the accidental parting of any of these lines, a cable should be stretched along the axis of the entire raft, and made fast to the steamer.

The intervals left between the partial rafts, and the number required to make up a tow, will be governed by the anticipated roughness of the water. In smooth water, an ordinary tug will conveniently draw forty pontons.

Each partial raft should always have a crew of four men provided with oars for steering, and with spare lashings for repairing damages.

When it is required to transport carriages they may be taken apart and packed into the pontons; but if the water is comparatively smooth the following is a better method: The partial rafts are formed of two pontons covered with a platform, thus presenting the appearance of one bay of a bridge. This platform, which is 27 feet by 13 feet, will carry four ordinary wagons, or four ponton wagons if they are unlimbered.

This method of moving the ponton trains was repeatedly used in the campaigns of the army of the Potomac, and it was found to be more safe and expeditious than to transport them in barges.

On the return from the peninsula to Washington in the summer of 1862, the rafts encountered a heavy gale in Chesapeake Bay, but escaped without injury.

CHAPTER IV.

BRIDGES WITH THE BRIDGE EQUIPAGE.

There are four methods of constructing a ponton bridge—by successive pontons; by parts; by rafts; and by conversion.

In order to secure simplicity and brevity of description, the general principles which govern these different methods will first be set forth, reserving the tactical details for another subdivision of this chapter.

BRIDGE BY SUCCESSIVE PONTONS.

Method of construction.—(Plate XI.) The location of the bridge having been selected, the ponton wagons are brought as near the river bank as practicable, with the rear of the carriage toward the stream.

The pontoniers are divided into detachments of twenty men each, for the purpose of unloading. The pontons are unlashed and slid from the wagon bed into the water; cables are attached to the anchors; one of the former is coiled in the bow of each ponton with its anchor on top, the flukes projecting over the gunwale.

Those pontons which cast up-stream anchors are moored above the approach to the bridge, and the others below.

The balks are piled on the left and the chess on the right of the roadway, both near the entrance to the bridge.

The pontoniers are again formed and divided into sections for constructing the bridge, which is executed in the following manner:

A trench about one foot in width and depth is excavated to receive the abutment sill; this should be laid horizontally, and exactly perpendicular to the axis of the bridge; it is secured by four pickets, two driven in front and two in rear, about eight inches from each end.

A ponton is brought up opposite to the abutment, and close to the shore.

The two cable men each drive a picket in the river bank, one thirty paces above, and the other the same distance below, the

bridge; to these they make fast the shore-lines, the free ends of which they carry with them into the ponton.

The front rank of lashers step into the ponton, provide themselves with two lashings each, and station themselves opposite the lashing hooks facing toward the shore.

The balk carriers bring up five balks; one end of each is delivered to a lasher who places it with its down-stream edge over its lashing hook, and its cleat against the outer edge of the exterior gunwale. He then takes one turn with a lashing around the balk and hook.

The ponton is pushed off by the balk carriers until they can engage the cleats of the shore ends on the abutment sill. The down-stream edge of the balk must be over the score in the sill. The cable men, under the direction of the officer in charge, adjust the position of the ponton by means of the shore lines, which are then made fast to the mooring posts.

As soon as the first set of balks is laid, a chess is placed on edge in the trench above mentioned, and in contact with the ends of the balks. Its upper edge should be one and a half inches above the balks. Earth is rammed behind it, crowding it firmly against the balks.

Two men, one standing on the first and second, and the other on the fourth and fifth balks, receive the chess from the chess carriers, and lay them with their scores exactly in the axis of the bridge. Each chess must be pushed firmly against that which precedes it. The covering is carried to within one foot of the ponton.

The ponton which has cast the first up-stream anchor, having dropped down to the head of the bridge, is entered by the cable men—the man in the bow taking the cable of the up stream anchor which he finds in it, the other receiving the cable of a down-stream anchor from one of the anchor detachment. The rear rank of the section of lashers also enters this ponton.

Five balks are brought up as before; the ends are delivered to the lashers in the second ponton, which is pushed off; the shore ends of the balks are delivered to the lashers in the first ponton, who place them on the down-stream side and in contact with those of the first set, their cleats against the outside of the interior gunwale. They lash the balks firmly together and to the lashing hooks at both gunwales, and then step into the third ponton.

When a bay is completely covered with chess, the side rails

are laid. They are placed directly over the outside balks, to which they are lashed at three points—at the middle, and immediately over the axis of each ponton, at which point the two side rails and balks of two bays lap and are all lashed together.

The side rail or rack lashing is made by passing a balk lashing, twice if doubled and three times if single, around the side rail and balk, and, after making it fast, twisting it tightly with a rack-stick.

Each anchor boat is manœuvred by one non-commissioned officer, who steers, and by four men who row it. The up-stream anchor pontons are conducted to the line of anchors; the two bow oarsmen boat their oars, prepare the anchor, and cast it on the line opposite to the point at which its cable is to be attached to the bridge. The bow men pay out the cable and allow the ponton to float down to the head of the bridge, where its bow mooring post is made fast to that of the nearest ponton. The crew pass ashore after another ponton.

The down-stream anchors are cast in a similar manner. The ponton is pulled up to the head of the bridge, the cable turned over to the cable man in the preceding ponton, the ponton secured as in the previous case, and the crew pass on shore.

The pontons that do not cast anchors are conducted to their places by a detachment of the down-stream anchor section.

In constructing a ponton bridge there are two points that require particular attention: the anchorage and the lashing; the men who are entrusted with their execution should be selected from the most intelligent and experienced pontoniers in the command.

The anchorage.—The distance of the anchor from the bridge should be at least ten times the depth of the stream; with a less distance the bows of the ponton would sink too deeply in the water.

The direction of the cable when made fast to the bridge must coincide with that of the current, *i. e.*, a ponton in the bridge must have the same position which it would assume if riding freely at anchor.

The chief of the anchor boat, before turning the cable over to the cable men, must make sure that the anchor has a firm hold on the bottom; if there is any doubt on this point he must recast the anchor.

It will be remembered that the cable is not finally made fast

to the ponton which casts its anchor, but to the one following it in the bridge; and due allowance must be made for this in selecting the place for casting anchor.

The number of anchors required will depend somewhat on the strength of the current. It is generally sufficient to cast an anchor up stream for every alternate ponton, and half that number down stream; but where the current is very rapid it may be necessary to anchor every up-stream boat, especially near the middle of the bridge.

The number of anchors cannot be much diminished, however moderate the current, as the anchorage has a very marked effect in checking the horizontal oscillation to which bridges are subject when troops are marching over them; and for this reason it is frequently advisable to increase the number of down-stream anchors. A down-stream cable is never attached to a ponton that is not anchored up stream.

The lashings.—With respect to the lashing, the corresponding balks of adjacent bays lap each other by six feet, and are lashed together and to the gunwales at two points about five feet apart. Thus a strong splice is formed, making five continuous beams running the entire length of the bridge.

This method of arranging the balks adds greatly to the strength and stiffness of the bridge, and possesses a marked advantage over the Austrian system, in which the balks merely meet over the axis of the ponton without lashing. The stability of the bridge is further increased by the manner of placing and securing the side rails.

To dismantle the bridge.—The material is supposed to be transferred to the shore opposite to that from which the bridge was constructed.

The side rails are removed from the first bay, and the lashings and rack-sticks thrown into the nearest ponton. This operation is continued, the removal of the rails preceding that of the chess by one bay.

The chess are removed from the first bay by two men standing on the uncovered balks, who hand them to the carriers to pile on the shore.

When the first ponton is uncovered, the balk lashings are removed and put into the locker. The balk carriers drag the balks on to the bridge, shoulder, and carry them off. The cable men detach the shore lines, and coil them in the ponton. The abutment sill is also placed in this ponton.

When the second bay is uncovered and its balks unlashed, the latter are seized by the balk carriers and dragged on the bridge. This operation draws the first ponton along-side of the second, into which the cable men step; the first ponton is then rowed across the river by the anchor section.

The up-stream cable man moves from each ponton as it is dismantled into the next, unmooring and turning over those which are anchored to the up-stream anchor section, who weigh the anchor and row to the shore.

The down-stream anchors are weighed as soon as the pontons to which they are attached are dismantled.

BRIDGE BY PARTS.

Method of construction.—(Plate XI.)—The abutment bay is formed as in the previous method. The parts are constructed at suitable points along the shore above the bridge, and for each is required a detachment of twelve men and the material for three bays.

They are constructed as follows:

A ponton is moored bow and stern close to the shore, and five chess are temporarily laid from the bank to its interior gunwale, for the convenience of the pontoniers during the construction of the part.

The other two pontons are brought up in succession, and two bays are constructed in the ordinary manner, except that six chess are omitted from the roadway at both ends. Twenty-six chess and seven balks are loaded on the part thus formed, which is then pushed off and conducted to the line of up stream anchors, where it casts its anchor and drops down to its place in the bridge.

The first part is connected with the abutment bay by the pontoniers on shore, who construct one length of bridge flooring in the usual manner, to join the abutment ponton with the first ponton of the part.

The other parts are united, as they come in position, by bays formed from the balks and chess with which they are loaded.

The down-stream anchors are cast by separate pontons provided for the purpose; and it may sometimes be necessary to cast the up-streams anchors in the same way, as the parts are not easily managed in a rapid current.

When the current is moderate, the parts may be constructed below as well as above the bridge.

Method of dismantling.—The parts are separated by removing the connecting bays, and loading the balks and chess of which they are formed, on the nearest part. Each part is next drawn by its cable to the line of up-stream anchors, and its anchor weighed; and it is then rowed to the shore, where it is dismantled.

The material of the abutment bay is carried off in the abutment ponton.

When it is impracticable to weigh the anchors as above directed, buoys are attached to the cables, and they are abandoned to be picked up afterward by the anchor boats.

BRIDGE BY RAFTS.

Method of construction.—(Plate XI.)—The abutment bay is laid in the same manner as in the last method, and the rafts differ from the parts only in having the roadway completed—that is, the six chess at each end are not omitted. The rafts are not loaded with extra balks and chess, but are provided with two false balks, 6 feet 9 inches by 5 inches by 5 inches, and with four rack collars and wedges. (Plate II, Fig. 5.)

The rafts cast their up-stream anchors, and drop down to their places in the bridge. The outer pontons of the adjacent rafts are in contact, and are lashed together bow and stern by their mooring posts. False balks are laid over the side rails of the two rafts at their junction; and two rack collars embrace each false balk, and the side rails and balks under them. These collars are placed on each side, and two feet from, the junction of the side rails. The wedges are driven between the false balks and the tops of the collars.

The bridge is dismantled by removing the false balks, and then proceeding as in the previous method.

As this method is seldom employed, it has not been considered advisable to carry collars and false balks in the ponton divisions. The collars are transported in the supply division, and the false balks are made, when required, by cutting a common balk into four pieces.

BRIDGE BY CONVERSION.

Method of construction.—(Plate XI.)—The position of the bridge having been determined, and the width of the stream

accurately measured,* a suitable place at some distance above the position of the abutment is selected for the construction of the bridge. This place may be at a considerable distance from that which the bridge is to occupy; it is frequently on some tributary of the stream to be bridged, out of sight of the enemy's shore.

The bridge is constructed parallel to the shore. Side rails are lashed on all except the extreme bays. The balks, chess, etc., for the abutment bay on the enemy's side are embarked on the next to the last bay of the bridge. A ponton is lashed to the last ponton in the bridge. This contains, in addition to the articles necessary for constructing the abutment, two strong pickets. The up-stream anchors are deposited in the bows of the boats on the wheeling flank; ten or fifteen yards of their cables are coiled, the remainder being stretched along the bridge. Two strong spring-lines are extended and lashed—the one over the bows, the other over the sterns, of all the pontons. These lines should be considerably longer than the bridge, and the ends are coiled on the platform. The bridge is then allowed to float down to within fifteen yards of the first abutment.

The material for the first abutment and bay is brought down in a ponton. Two strong pickets are planted to receive the spring-lines, and two to receive the shore lines, which are coiled on the platform between the first and second pontons.

The wheeling flank is pushed off, and men are stationed in the bow and stern of each ponton, with oars and boat-hooks, to increase or retard the progress of their ponton, as may be necessary. A detachment is stationed at the first abutment to manœuvre the spring-lines; another to prevent the pivot flank from touching shore; a turn of the shore-line is also taken around the mooring-post of the ponton, and this line is eased off, as the case may require. The anchors are cast as the pontons in which they are carried come in the proper places, and their cables are shifted to the pontons to which they are to be attached. The progress of the bridge is checked when it arrives opposite the abutments—which should be constructed during the conversion of the bridge, if the force be strong enough.

* The width of a river may be measured by the following method: Let A be the station of the observer on the river bank; C, an object on the opposite bank. By means of a pocket sextant or compass lay off a base-line A B, at right angles to A C; move along A B until a point D is found where the angle A D C will measure 45°; then D A = A C, or the distance required.

The down-stream anchors are cast by the spare pontons, as in the bridge by successive pontons.

Method of dismantling.—This manœuvre is rarely executed except by an army in retreat, closely followed by the enemy.

The abutment bays are dismantled; the spring-lines are left fastened to the pickets; buoys are attached to the down-stream cables, which are cast off; the up-stream cables are lengthened out with spare rope; a strong line is passed from the next to the last ponton to the shore below the bridge. The bridge is allowed to swing around; the up-stream cables are eased off, also the upper spring line. When about half the wheel has been completed, the pontons form such an angle with the current that the tendency of the bridge is no longer toward the required direction, but to move obliquely toward the other shore; the strain on the lower spring line becomes very great, and the pontoniers must haul in on the shore line, and use their oars and boat-hooks.

After the wheel has been effected, the bridge is floated down stream behind an island, or to some other place sheltered from the enemy's fire, and is there dismantled.

GENERAL REMARKS ON PONTON BRIDGES.

Comparison of the four methods.—The method of construction by *successive pontons* possesses the advantages over the others of being applicable to all streams, whatever may be their velocity, and of requiring the minimum quantity of materials, the fewest pontoniers, and the shortest time for its accomplishment. The labor, however, of constructing a bridge by this method increases rapidly with the number of bays. Thus the balk and chess carriers, in constructing a bridge of forty bays, are obliged to walk six and three-quarters miles; in one of fifty bays, nearly ten and a half miles; of sixty bays, fourteen and three-quarters miles; and of one hundred bays, forty miles. When, therefore, the bridge is to be more than forty bays in length, the methods by successive pontons and by parts should be combined as follows:

The bridge is commenced, at both ends if possible, by successive pontons, and is pushed on rapidly toward the middle of the stream. The two portions thus formed are connected by parts, which are constructed in the meanwhile along the river bank above the bridge.

The *method by rafts* is employed when the passage of a river

is to be forced, and when the rafts can be constructed unobserved by the enemy—in which case the pontoniers will be exposed to fire but a short time, that is, while the rafts are floating into position and being connected.

In order that this method of construction should be successful, the current must be moderate, and there must be, at a reasonable distance above the bridge, positions where the rafts can be constructed unsuspected by the enemy. Such positions would be afforded by islands or tributaries in our possession.

This method is also employed when the bridge is liable to injury from floating bodies, as the portion threatened can be readily disconnected, dropped out of the bridge, and restored to its place when the danger is past.

This species of bridge may be used by any army hard pressed in retreat, as the rafts on the enemy's side of the river may be disconnected and conducted to a place of safety, even while the rear guard is passing over the other end of the bridge.

The *construction by conversion* is a still more delicate operation. To insure success the current must be moderate, the holding ground good, and the pontoniers skilful, intelligent, and cool. The awkardness of a single man, the dragging of an anchor, or the parting of a cable, may cause the failure of the entire operation.

Draw in the bridge.—In navigable streams, it is frequently necessary to provide a draw in the bridge; which is effected by introducing two or more rafts, constructed as described in the third method, and situated in the part of the bridge through which it is most convenient for vessels to pass. To open the draw, it is disconnected from the adjacent pontons, and is allowed to drop out of the bridge by paying out the cable of its up-stream anchor—one end of a line being attached to the bow of its middle ponton, and the other to the stern of the second ponton from the opening on the side to which the raft is to be conducted. As the cable is slackened the raft will swing into the required place, where it is secured by the line above mentioned. The raft is replaced in the bridge by casting off the bow line and hauling in the cable of the up-stream anchor. The draw may be formed of two rafts, one dropping to the right, and the other to the left of the opening.

The abutment bay.—There are four methods of constructing this bay.

In streams where the *level of the water is not likely to vary*

sensibly during the continuance of the bridge, two cases may arise:

First. When the water at the distance of twenty feet from the abutment is deep enough to float a ponton when loaded. The course here pursued is that which has been described above. (Plate XII, Fig. 2.)

Second. When the ponton cannot thus be moored. Its place is then supplied by a trestle, (Plate XII, Fig. 1,) which is established as follows, (Plate XIII, Fig. 5):

A ponton is brought opposite the abutment sill; two long balks are laid from its interior gunwale to the shore; a trestle cap is suspended from these by lashings, and the claws of two short balks are engaged on the cap. The ponton is pushed off until the shore ends of the short balks can be engaged on the abutment sill, or, in case of very shallow water, on the cap of a trestle previously laid from shore; the legs are inserted in the mortises of the cap; the shoes placed and keyed; the legs driven down into the bed of the river; the suspension chains adjusted; the false legs inserted; and the ponton and long balks withdrawn. When it is desirable to establish the flooring more than two feet above the water, the method indicated on Plate XIII, Fig. 6, may be employed.

The remainder of the construction proceeds in the usual way.

It is well to remark that all bays which are sustained by fixed supports, at one or both of their extremities, should be re-enforced—by laying two extra balks, one between the first and second balks in contact with the second, the other between the fourth and fifth, in contact with the fourth—in order that they may have the same strength as those supported by pontons. This is necessary, because the distance between the bearings is greater and the strain from a shock is more severe, with fixed than with floating supports.

If the *pontons rise and fall*, as is the case in tidal streams, the floor of the abutment bay is constantly changing its inclination, while that of the remainder of the bridge continues horizontal. This hinging motion on the first ponton may be provided for in two ways:

First. By equipping the first ponton with a saddle. (Plate XII, Fig. 3.) Two saddle transoms are engaged on the gunwales of the ponton; they are placed five inches inside of the extreme lashing hooks, and on these transoms is placed an

abutment sill resting in the recess formed by their cleats. Seven short balks connect this sill with that on shore, and five long balks, with the second ponton—where the lashings are made in the usual manner. The side-rails of the first and second bay should not lap, but merely meet over the saddle sill. Both bays may be re-enforced.

This method is employed when the bridge is to be subjected to very heavy loads, or when it is to be used as a thoroughfare for a long time.

Second. When the loads are to be moderate, and the bridge is for temporary use, the hinging bay may be arranged in the following manner (Plate XII, Fig. 4):

The short balks from the fixed support are engaged on the interior gunwale of the first ponton, and the long balks of the second bay are lashed to both gunwales of this ponton.

When the river bottom is of mud or sand, and shoals gradually, the bridge may be built as described in the article on successive pontons, placing the abutment sill about two feet above high-water mark. As the tide falls, the pontons ground successively, forming a gentle ramp from the abutment to the floating portion of the bridge.

Bridge with extended intervals.—This method is represented on Plate XII, Fig. 5. It has the advantage of giving a bridge one-fourth longer for the same number of pontons, but does not give the same strength or stiffness as the ordinary method. It answers, however, very well in small streams when the bays are all re-enforced—and, even without this precaution, when proper care is taken in passing the loads over it.

BRIDGES WITH ADVANCE-GUARD EQUIPAGE.

As the canvas ponton can be easily carried a considerable distance by six or eight men, it is not necessary to unload and assemble the pontons on the river bank. Some convenient locality in the vicinity of the position which the bridge is to occupy is selected; the ponton frames and chests are unloaded; the cover is spread on the ground, and one of the side frames laid upon it. (Plate VIII, Fig. 3.) The tenons on the transoms are inserted in the mortises of this frame, and the second side frame is placed on top of the transoms; a rope (Plate VIII, Fig. 2) is passed through the rings of the side frame, made fast and twisted with the rack-stick; the frame is then turned over on the canvas, and the cover is lashed. The ponton is then carried to the river and launched.

Eight men are required for this operation. After the ponton is launched, it is provided with an anchor and cable, paddles, boat-hooks, lashings, rack-sticks, a scoop-shovel, and scoops.

These preparations having been made, the bridge is constructed by successive pontons in the manner already described.

As the canvas pontons should never be allowed to ground, the necessity for the use of trestles in the abutment bays is more frequent with the advance-guard train than with the reserve equipage.

NUMBER OF PONTONIERS REQUIRED.

The number of pontoniers required for the execution of the operations above described, with bridges of different lengths, may be ascertained from the following table:

Pontoniers required for a bridge by successive pontons.

Sections.	One division.		Two divisions.		Remarks.
	Non-com. officers.	Privates.	Non-com. officers.	Privates.	
1	1	4	1	8	Abutment and side rails.
2	1	4	2	8	Up-stream anchors.
3	1	4	2	8	Down-stream anchors.
4	1	10	1	10	Balk carriers.
5	0	10	0	10	Lashers.
6	0	2	0	2	Cable men.
7	1	22	1	22	Chess carriers and coverers.
Total..	5	56	7	68	

Sections.	Three divisions.		Four divisions.		Remarks.
	Non-com. officers.	Pri. vates.	Non-com. officers.	Pri- vates.	
1	1	10	1	10	Abutment, and assist fourth section.
2*	2	8	4	16	Up-stream anchors.
3*	2	8	2	8	Down-stream anchors.
4	1	10	1	20	Balk. Two reliefs for four divisions.
5	2	8	2	8	Lashers.
6	0	3	0	3	Cables. Alternate on up-stream cables.
7	1	22	1	44	Chess carriers and coverers. Two reliefs for four divisions.
8	1	8	1	8	Side rails.
Total..	10	77	12	117	

* The strength of these sections will depend on the rapidity of the current.

For a short bridge, one commissioned officer is sufficient; for a long bridge there should be three—the commanding officer, one at the head of the bridge, and one superintending the anchor sections. When the number of pontoniers is insufficient, sections four and seven may be detailed from troops of the line.

For the construction of a bridge by rafts or parts, there will be required one non-commissioned officer and twelve men for the abutment bay, one non-commissioned officer and twelve men for each raft or part, and two non-commissioned officers and eight men for the anchor detachment.

When the bridge is to be constructed from each shore by successive pontons, and in the middle by parts, there will be required for each shore, one officer, seven non-commissioned officers, and sixty-eight privates (see table for two ponton divisions), and for each part, one non-commissioned officer and twelve men.

TRESTLE BRIDGES.

They are of two descriptions: First, those built on the land; second, those built over a water-course. Under the first head are included bridges built over dry ravines, over marshes, and over streams too shallow to float a ponton, but where the pontoniers can wade when placing the trestles. This species of bridge is constructed in the following manner:

Trestle bridge on land.—(Plate XIII, Fig. 1.)—The abutment sill is placed as in ponton bridges, and cords twenty feet long are stretched horizontally from the ends of the sill, in a direction parallel to the axis of the bridge. The ends of these cords will indicate the position of the cap of the first trestle, and from their height above the ground may be estimated the distance which the legs are to be thrust through the cap.

The members of one trestle are brought up and assembled in a horizontal position, with the cap toward the abutment and the points of the legs over the places they are to occupy. The trestle is then raised into a vertical position, and the exterior balks of the abutment bay are placed.

If the cap is now found to be out of the proper level, the correct position should be marked on the legs with chalk, the trestle be lowered to the ground, the correction be made, and the trestle be again raised; the five abutment balks are then placed.

The remaining trestles are placed in a similar way; and the flooring is executed as in ponton bridges.

Trestle bridge over a water-course.—(Plate XIII, Fig. 2.)—The abutment sill is laid in the usual manner, and a raft (Plate XIII, Figs. 3 and 4) is constructed of two pontons, connected by two balks lashed to the outer lashing hooks. The raft is partially decked by laying chess between and parallel to the balks, thus covering the first ponton and part of the second.

On this raft the members of the trestles are embarked—the caps and legs on the balks and over the second ponton, the chains on the deck, and the false legs and shoes in the bow and stern of the first ponton. The raft is brought opposite to the abutment, and is, at the commencement of the operation, held in position by the cable men with their shore lines; afterwards, by cables from up and down stream anchors.

A trestle is assembled with its cap resting on the ends of the balks which overhang the first ponton of the raft, its legs horizontal and pointing toward the abutment. The trestle being righted and the five abutment balks engaged on its cap, the raft is pushed off and the balks are engaged on the abutment sill. The position of the trestle is accurately adjusted by the cable men, and the legs are thrust down and driven with a maul into the bed of the stream. To allow for the tendency of the latter to spread apart when driven into the ground, they should, when first touching bottom, make a less angle with the vertical than 15°. As soon as the legs are settled into place, the chains are toggled and the raft disengaged. The remaining trestles are similarly placed, and the roadway is finished as usual.

The trestle bridge depends for its stability upon the strength of the claws on the balks and upon the immovability of the abutment sill; the importance of picketing the latter strongly will therefore be apparent.

Though the trestle is in every respect inferior to the ponton bridge, yet the facility with which trestles may be constructed on the spot, whenever the requisite lumber can be obtained, renders this method very important. There are always an abundance of men in an engineer company who can construct rough trestles, which will answer every purpose.

The trestle bridge is also useful on shallow tidal streams,

where the pontons would ground at low water on an uneven bottom.

PONTON DRILL.

Although the varied circumstances under which military bridges are constructed in the field preclude the possibility of executing this kind of work with the precision that should characterize other military movements, yet to insure the proper division of labor and promptness of execution, a routine drill for the instruction of engineer troops is necessary, the details of which should be as closely followed in actual service as circumstances will permit.

The drills for the construction of bridges by successive pontons, by trestles on land, and by trestles over a water-course, will, either separately or combined, cover all cases which can occur in constructing a bridge by any of the methods described in the foregoing pages.

To construct by successive pontons.—(Plate XI.)—Each ponton wagon is brought as near as practicable to the river bank, the rear toward the stream. The ponton is unlashed and slid into the water. Twenty men are required for this operation.

The balks are then piled on the left of the entrance to the bridge, in the following manner: Two balks are laid on the ground parallel and eighteen feet apart; across these a layer of balks nearly in contact; then two chess over the first two balks; then another layer of balks, etc.

The chess are piled on the right side of the bridge as follows: Three balks are laid on the ground, parallel to each other and four feet apart; on these a course of ten chess, nearly in contact; across these ten more chess, etc.

Each ponton, after it is launched, is provided with five oars, one boat-hook, two scoops, two bundles of balk lashings, (each containing ten lashings,) and one anchor, with cable attached. The cable is coiled in the bow of the ponton; on the coil the anchor is laid with its flukes projecting over the bow. Those pontons destined to cast up-stream anchors are moored above the entrance to the bridge; all the others, below.

The above dispositions having been made, the company is formed in two ranks and divided as follows (Plate XI):

Sections.	Non-commissioned officers.	Men.	Remarks.
1	1	8	Abutment.
2	2	8	Up-stream anchors.
3	2	8	Down-stream anchors.
4	1	10	Balk carriers.
5	2	8	Balk lashers.
6	0	2	Cablemen.
7	1	22	Chess carriers.
8	1	8	Side rails.
Total.....	10	74	

The captain superintends the whole operation. One lieutenant has charge of the anchor detachments, another of the head of the bridge. The pontoniers in each detachment are numbered from right to left, the front and rear rank men of each file having the same number. The captain commands: CONSTRUCT THE BRIDGE!

At this command *the first section, abutment,* excavates a trench one foot deep to receive the abutment sill. In placing the sill great care should be taken that it is horizontal, and exactly perpendicular to the axis proposed for the bridge. The sill is firmly secured in place by pickets driven in front and rear, about eight inches from each extremity. As soon as the balks are in place, a chess is arranged against their ends, its upper edge on a level with the surface of the chess forming the roadway. It is secured by two pickets, and by packing earth in rear of it.

The aproach to the bridge is then rendered easy by cutting down and leveling the bank, if necessary.

The second section, up-stream anchors, is divided into two half-sections, each containing one non-commissioned officer and four men. Each half-section embark in an up-stream ponton. The non-commissioned officer steers. The ponton is pulled up to the line of up-stream anchors, which is indicated to the steersman by the lieutenant on shore. Arriving on this line, and opposite to the place where the cable is to be attached to the bridge, the anchor is cast by Nos. 1 and 1, who pay out the cable as the boat floats down to its place in the bridge, when they hand it over to the cable detachment. The anchor detachment then passes over the bridge to the shore for another ponton.

The third section, up-stream anchors, is divided into half-sections. The first half-section cast the down-stream anchors in a manner similar to that pursued with the up-stream anchors;

then pull up to the bridge head, and hand over their cable and boat to the cable detachment. The second half-section embark in the pontons that do not cast anchors, pull them to their places in the bridge, and hand them over to the cable men.

The fourth section, balk carriers.—This detachment, having placed five balks on the ground parallel to the axis of the bridge and two feet apart, take their places, the front rank opposite the front ends and rear rank opposite rear ends of the balks. The chief of section commands: LAY HOLD! RAISE! SHOULDER! FORWARD! Each file seizes a balk, raises it, the front rank to the right the rear rank to the left shoulder, and moves in line to the head of the bridge. The chief of section commands: HALT! LOWER! At this command the front rank pass their ends of the balk to the lashers on the ponton, and, stepping back, relieve the rear rank of their ends of the balks. As soon as the lashers have secured the balks to the ponton, the chief of section commands: SHOVE OFF! The front rank push steadily against their ends of the balks until the ponton has attained its place, let go the balks, which are received by the lashers, and rejoin the rear rank. They are marched off the bridge by the left flank, keeping close to their right-hand side of the bridge.

The fifth section, lashers.—The front rank enter the first ponton. The chief of section takes a bundle of lashings from the locker in the stern and distributes them; each man has two. They then take their places opposite the lashing hooks, facing toward the shore. They receive the ends of the claw-balks presented to them by the balk-carriers, and engage the claws on the inner gunwale. As soon as the second ponton is brought to the head of the bridge, the rear rank taking hold of hands to steady themselves, walk along the balks already laid, into the second ponton, where they take a position similar to the front rank. When the second set of balks is brought up, they receive the ends from the balk-carriers, lay them in place, overlapping the outer gunwale six inches, give one turn of the lashing, and throw their weight on the balks to keep them in position while the boat is pushing off. In the meanwhile the front rank adjust the other ends of these balks, and lash them firmly to both gunwales of the first ponton by the knot shown on Plate XII. The front rank then pass into the third ponton, etc.

The sixth section, cable detachment.—Drive two pickets, one thirty paces above, and one thirty paces below, the axis of the bridge. To each of these a shore line is made fast, the free

ends of which are carried to the bow and stern of the first ponton. The front-rank man attends to the bow, and the rear-rank man, to the stern lines. When the first ponton is pushed off, it is brought into position by means of these lines. The lieutenant in charge at the head of the bridge then commands: MAKE FAST! Both lines are drawn taut, and made fast to the mooring post by the knot shown on Plate XII. The cable men then step into the second ponton, receive the cables from the anchor men, bring the second ponton into place as soon as it is pushed off, and hold it so until the second bay is nearly covered. They then step into the third ponton, carrying the cables with them. When the third bay is nearly covered, the up-stream cable is made fast, but the down-stream cable is carried to the fourth ponton, etc. The bridge is usually anchored from every second ponton up stream, and every fourth down stream.

The seventh section, chess carriers.—The first file stand on the balks to be covered, (one on the first and second, the other on the fourth and fifth balk,) facing toward the shore; they receive the chess from the carriers and place them, shoving each hard up against the preceding one. The remainder of the detachment bring up the chess; each man carries a chess under his right arm, the forward end raised well up; he marches on the right side of the bridge, delivers the chess to the coverers, then passes back to the pile by his right of the bridge.

The eighth section, side rails.—Nos. 1 and 1 carry up-stream, Nos. 2 and 2 down-stream rails; they are carried in the same manner as the balks. Nos. 3 and 3 lash on the up-stream, Nos. 4 and 4 on the down-stream side. The side rails are placed immediately over the outer balks, and are lashed by passing a lashing, twice if doubled and three times if single, round the balk and rail, tying it loosely in a half bow-knot, (Plate XII,) and then twisting it tightly with a rack-stick. There are three lashings on each rail, one at the middle, another over the axis of each ponton embracing two balks and two rails.

To dismantle by successive pontons.—The sections operate in an inverse order. The captain commands: DISMANTLE THE BRIDGE!

The eighth section, side rails.—Each file removes the lashings from and carries off a side rail. The lashings are thrown into the stern of the nearest ponton.

The seventh section, chess carriers, remove the chess, which are handed to them by the coverers, and passing to the shore form a pile on the right of the approach.

The sixth section, cable detachment, unmoor the pontons and turn them over to the anchor men.

The fifth section, balk lashers.—But one rank of this detachment is required. They unlash the balks as soon as uncovered. The chief of section forms a bundle of the lashings and throws it into the locker.

The fourth section, balk carriers.—As soon as the balks of the first bay are uncovered, the front rank seize the ends of the balk and drag them on the bridge, passing through the rear rank. The balks are then removed by the same commands and in the same manner as in constructing the bridge. The balks are piled to the left of the entrance to the bridge.

The third section, down-stream anchors, weigh down-stream anchors and bring the pontons to shore.

The second section, up-stream anchors, weigh up-stream anchors and bring the pontons to shore.

The first section, abutment.—The first abutment sill is taken up as soon as the first set of balks is removed. The detachment embark with it in the first ponton, when the bridge is transferred to the bank opposite to that from which it was laid.

In all the above manœuvres, the detachments, when moving on the bridge, will keep as close to their right-hand side of it as possible.

Loading the ponton on the wagon.—After the material is brought to the shore, the ponton wagons are loaded as follows: The pontoniers are divided into sections of one non-commissioned officer and twenty men each. The seven balks are placed on the wagon and secured by the dowels. The ponton may then be raised to its place by one of the following methods, if the nature of the shore does not permit it to be floated upon the wagon backed into the water to receive it.

First. (Plate XV, Fig. 1.) When two strong casks can be procured, the ponton is placed in rear of the wagon with its stern toward, and about fourteen feet from, the rear ends of the balks. The stern is raised sufficiently to allow the two casks to be placed under the ponton directly below the stern-lashing rings, so that the chafing battens rest on the bilges of the casks. The pontoniers, who are stationed on each side of the ponton, seize it by the gunwales and urge it forward toward the wagon, rolling it on the casks. As soon as the stern rests on the side rails, rack-sticks are laid on the latter and the ponton is rolled into place.

Second. (Plate XV, Fig. 2.) The wagon is unlimbered and the front part lowered to the ground; in this position the balks form an inclined plane, up which the ponton can be slid into place. The wagon is then limbered up. To facilitate the latter operation, the ponton should be slid about five feet beyond its proper position in the wagon. The load will then be nearly balanced over the rear axle, which will allow the front part to be easily raised upon the limber.

Third. (Plate XV, Fig. 3.) Holes about eighteen inches in depth are dug in the ground to receive the rear wheels of the wagon; when the wheels are thus lowered, the rear ends of the balks will rest on the ground, and on the inclined plane thus formed the ponton is slid into place.

Fourth. (Plate XV, Fig. 4.) The ponton is placed twenty feet from the wagon, and parallel to the position it is to have when loaded. A chess is laid on the side rail of the wagon nearest to the ponton. Three balks are placed so that one end of each shall rest on the ground touching the ponton, and so that points five feet from the other end shall rest on the chess above mentioned. The balks are perpendicular to the side rail; the first rests on it over the forward wheel, the third in front of and in contact with the hind wheel, the second half-way between the two. The ponton is slid up the ramp thus formed until it touches the hind wheel, when the lower ends of the balks are raised until the ponton can clear the wheel; it is then pushed into place, and the chess and three balks removed.

To construct a trestle bridge on land.—(Plate XIII, Fig. 1.)—The wagons are unloaded; the balks and chess are piled as directed for the ponton bridge; the different members of the trestle are piled on the right of the chess; and the company is formed in two ranks, and divided as follows:

Sections.	Duty.	Non-com'd officers.	Men.	Remarks.
1	Abutments	1	8	Construct the abutment and approaches.
2	Trestle carriers	1	8	Bring up the members of trestles.
3	Trestle builders	1	8	Construct the trestle and adjust the balks.
4	Balk carriers	1	10	Bring up and place balks.
5	Chess carriers	1	22	Twenty carry, and two place, the chess.
6	Side rail	1	8	Bring and lash side rails.
Totals		6	64	

Each detachment is numbered from right to left, the front and rear rank men of each file having the same number. The captain superintends the entire construction. The lieutenant superintends the trestle builders. The former then commands: CONSTRUCT THE BRIDGE! which is executed as follows:

The first section, abutment, excavate a trench one foot deep to receive the abutment sill. In placing the sill great care must be taken that it is horizontal, and exactly perpendicular to the axis of the proposed bridge. The sill is firmly secured by pickets, driven in front and rear about eight inches from each extremity. As soon as the balks are placed, a chess is arranged against their ends, its upper edge on a level with the chess forming the roadway; this is secured by two pickets, and by packing earth behind it. The approach is then rendered easy by cutting down and levelling the bank if necessary.

The second section, trestle carriers.—Nos. 1 and 1 and Nos. 2 and 2 carry the cap, passing rack sticks through its rings for this purpose. Nos. 3 and 3 carry the legs, Nos. 4 and 4, the false legs, shoes, and chains. These articles they deliver to the third section, and return for another load.

The third section, trestle builders.—The front rank take post on the right, and the rear rank on the left, of the bridge. No. 1 inserts the leg in the cap and adjusts the chain; No. 2 adjusts the false legs; No. 3, the shoe; No. 4 is stationed at the foot to prevent it from slipping. The chief of section lays off from the sill or last trestle the distance at which the new trestle is to be placed; he also measures the height at which the cap is to be raised above the ground, and from this estimates the distance the legs are to be thrust through the cap. Nos. 1, 2, and 3 raise the trestle; No. 4 prevents the foot from slipping. Nos. 3 and 4 hold the trestle erect, while Nos. 1 and 2 adjust the balks, which they receive from the balk carriers. When the cap is so high that it cannot be reached from the ground, the manœuvre is executed as indicated on the lower part of Fig. 1, Plate XIII.

The fourth section, balk carriers, place five balks on the ground, parallel to the axis of the bridge and two feet apart, and then take their places, the front rank opposite the front ends, and the rear rank opposite the rear ends of the balks. The chief of section commands: LAY HOLD! RAISE! SHOULDER! FORWARD! Each file seizes one end of a balk and raises it, the front rank to the right, the rear rank to the left, shoulder. They

move in line to the head of the bridge. The chief of section commands: HALT! LOWER! At this command, the front rank pass their ends of the balks to the trestle builders, and stepping back, relieve the rear-rank men and assist in placing the balks. The section is then formed in two ranks on the left of the bridge, and marched off by the flank.

The fifth section, chess carriers.—The first file of this section stand on the balks to be covered, one on the first and second, the other on the fourth and fifth, both facing the shore; they receive the chess and place them, shoving each chess hard against that which precedes it. The remainder of the section bring up chess, each man carrying one under his right arm, the forward end well up. He moves up on the right side of the bridge, delivers his chess to the coverers, and then passes back to the pile of chess by his right of the bridge.

The sixth section, side rails.—Nos. 1 and 1 carry side rails for the right, and Nos. 2 and 2 for the left of the bridge. Nos. 3 and 3 lash on the right, and Nos. 4 and 4, on the left.

The side rails are placed immediately over the outer balks; and are secured by passing a lashing, three times if single and twice if doubled, around the balk and side rail, tying it loosely in a half bow-knot, and then twisting it tightly with a rack stick. There are three of these lashings on each rail, one in the middle, and one over the axis of each ponton embracing two balks and two rails.

The greatest attention must be paid to securing the abutment sill, as on this, in a great measure, depends the stability of the bridge.

When, after raising the trestle, the cap is found to be out of place, it is better to lower the trestle to the ground and correct the error than to attempt doing so while it is standing.

To dismantle a trestle bridge on land.—The sections remain the same, operating in an inverse order.

At the command: DISMANTLE THE BRIDGE! the sixth section removes the side rails; the fifth section the chess; the fourth section the balks; the third and second sections overturn, dismantle, and carry off the trestles; the first section removes the abutments.

Trestle bridge over a water-course. (Plate XIII, Fig. 2.) The company is divided as follows:

Sections.	Designation.	Non-com. officers.	Privates.
1	Abutment	1	8
2	Trestle	1	8
3	Anchors, up-stream	1	4
4	Anchors, down-stream	1	4
5	Balk carriers	1	10
6	Cable men	0	2
7	Chess carriers	1	22
8	Side rail	1	8
	Totals	7	66

These sections have the same duties to perform as the corresponding sections in the construction of bridges by successive pontons, excepting the trestle section. At the command: CONSTRUCT THE BRIDGE! this section construct a raft, (Plate XIII, Figs. 3 and 4,) with two pontons, having two balks lashed to the gunwales. A deck is formed of chess laid parallel to the balks, and covering the first and part of the second ponton. The different members of the trestle are embarked on this raft. The caps and legs are laid alternately on the two balks over the second ponton; the chains, on deck over the first ponton; the false legs and shoes, in the bow and stern of the first ponton.

The raft is brought opposite to the abutment. The front rank operate on the up-stream, and the rear rank on the down-stream side of the bridge. The cable men hold the raft in position first by the shore lines, afterward by the cables delivered to them by the anchor section. Nos. 1 and 1, and Nos. 2 and 2, bring up a cap, lay it on its side on the ends of the two balks, and with its bottom toward shore. Nos. 1 introduce the legs into the mortises, Nos. 2 attach the chains, Nos. 3, the false legs, and Nos. 4, the shoes. The chief of section commands: RAISE! The trestle is righted. Nos. 1 step on the trestle and hold the legs to keep them from sliding through the mortises. The others receive and adjust the balks, which are passed to them by the balk carriers. The raft is pushed off. The cable men, directed by the chief of section, adjust the position of the trestle by means of the cables. Nos. 1 thrust down the legs, driving them into the river bottom; Nos. 2 hook the chains. The chief of section commands: DISENGAGE! All lift on the cap just placed

and sink the first ponton of the raft until the latter can be disengaged from the trestle.

The bridge is dismantled by bringing up the raft and reversing the operation just detailed.

EXPEDIENTS WITH INSUFFICIENT TRAINS.

Flying bridge.—This term is applied to any floating support anchored to a fixed point (usually in the stream), and driven from shore to shore by the oblique action of the current on its side.

Although these bridges do not afford a continuous communication, yet they possess some decided advantages, viz:

They are readily established, even over the most rapid streams.

They require but little material for their construction.

They may be worked by very few men.

They permit the passage of troops of all arms, and of the heaviest carriages.

The entrance to and exit from them is easy.

They do not interrupt navigation; and they are not liable to be injured by floating bodies which, either by accident or design, are carried down stream by the current.

The current should not be less than one yard per second.

To construct the raft.—The raft is formed of six pontons. (Plate XIV, Fig. 1.) Two pontons are lashed stern to stern, and to these a third, breaking joints. A second set similar to the above is placed at a distance from the first of twenty-six feet.

The two sets are connected by six balks *c*, over which four courses *d* are lashed; then fifteen balks *e*, are placed in a manner suitable for receiving the chess. The extreme chess are nailed down, and the outer courses secured by side rails.

The length of the cable should be at least one and a half times the width of the river. One, two, or three anchors are used, depending on the strength of the current.

The cable (Plate XIV, Fig. 2) is supported by pontons. The distance between the boats should be such that the cable shall not touch the water between the first boat and the raft. Each boat is fitted with a staging, composed of two short balks and a supporting block, on which the cable rests, and to which it is lashed.

The cable is also connected with the bow of the boat by a line

of such length that the boat is allowed to turn just enough to keep parallel with the raft.

After the raft is attached to the cable, it is passed from shore to shore once or twice, using a stern veering line if necessary, until the anchors are firmly embedded, and the cable is stretched; the two abutments are then constructed; these do not differ from the first bay of the ordinary bridge.

If the strongest current is nearer one of the shores, the anchor must not be cast in the middle of the stream, but nearer the other shore.

The proper angle for the axis of the boat to make with the current is about 55°. This angle is gradually increased on nearing the shore, until the way of the raft is diminished sufficiently to prevent it from striking the abutment with a shock.

The raft should be provided with spare cables and anchors ready for casting, in case the cable by which it is moored should part.

The flying bridge represented on Plate XVII was used at Chattanooga, during the late war, for crossing men and vehicles over the Tennessee River. It could carry four six-mule teams and wagons, besides infantry and cavalry. The cable was attached to an island above, and was supported on three floats. The connection with the boat was made by a rope fastened by both ends to the end of the cable, and passing through snatch-blocks at the bow and stern of the boat on the up-stream side, and around a windlass at the middle. By turning the windlass, any desired direction in reference to the current, and therefore any desired velocity, was readily obtained. Leeboards near bow and stern were used to catch the current, and increase the velocity when required. One man could manage the boat with ease.

Trail bridges.—(Plate XIV, Fig. 3.)—When the river is not more than one hundred and fifty yards wide, a sheer-line may be used in place of the anchor and cable; the sheer-line must be taut enough to keep above the water.

If the banks are not high enough, the sheer-line should be elevated at each shore by passing it over a frame formed of three poles, arranged like an artillery gin. A capstan, or block and fall, will be required to tighten the line from time to time as it stretches. Upon this line a pulley is fixed, so that it can run freely from shore to shore; through the eye of the pulley block a line is passed, one end of which is attached to the bow of the first, and the other to the bow of the second, boat forming

the raft. The raft is manœuvred in the same manner as in the flying-bridge; or one end of a line may be made fast to the running-block on the sheer-line, while the other passes through a snatch-block near the stern of the raft on the up-stream side; by hauling in or letting out this line the proper direction is given to the raft.

Rope ferries.—The rope-ferry is used when the velocity of the current is not sufficient to propel the raft. It consists of a raft or flat, provided with a standard near each end on the up-stream side. These standards are forked on top to receive the sheer-line, which is stretched across the stream in the same manner as for the trail bridge. The raft is propelled across the stream by men on its deck hauling on the sheer-line. Fig. 4, Plate XIV, represents two methods of constructing a flat-boat suitable for a rope-ferry.

Prairie raft.—It frequently occurs in the western country that expeditions, unaccompanied by regular ponton trains, are compelled to cross streams so situated that it is impossible to obtain timber, or other material, suitable for the construction of rafts or bridges. Under these circumstances, a raft may be constructed of two canvas pontons, (Plate XV, Fig. 8,) by means of which loaded wagons may readily be ferried over the stream. All the material required for such a raft is easily carried in one ponton wagon. The construction is as follows: The wagon to be floated is backed into the stream until the rear wheels stand in about one foot of water. A canvas ponton is placed on each side of the wagon, parallel to and one foot from it. A balk is placed against the tail-board of the wagon, and resting upon the gunwales of the pontons. A second balk is similarly placed against the front-board of the wagon. On each side of the wagon a strong rope is made fast to the front balk, passed under the axle-trees around the rear balk, and thence back to the starting point, where it is made fast. The raft and wagon are pushed into the stream, and, as soon as the latter is clear of the bottom, the balks are lashed to the gunwales of the pontons. A line is attached to the wagon pole, and coiled in the bow of one of the pontons. This raft may be conveyed across the stream either by rowing, or in the manner of a trail bridge. On approaching the opposite shore, it should be turned with the wagon pole toward the bank. As soon as the wagon grounds, the balks are removed and the wagon is drawn on shore by means of the rope attached to its pole. A single hinged canvas ponton,

which is readily packed in an ordinary quartermaster wagon, will suffice for the crossing, if the wagons are unloaded and taken apart.

Bridges from boats of commerce.—The same principles are applicable in this case as in that of ponton bridges.

The following additional precautions, however, must be observed:

As the boats are not usually of a uniform size, the length of the balks for each bay should be so proportioned to the capacity of the boat which sustains them, that the bridge will not be endangered, even when the bay is covered with as many men as can be crowded on it.

The boat next to each abutment must be strong and large.

Large boats should be selected for the strongest part of the current, so that they may be as much separated as possible. The bridge will then offer less obstruction to the current, and will also be in less danger from floating bodies.

The intermediate boats should increase or diminish in size gradually, to avoid a sudden change in the level of the roadway.

The gunwales of the boats should be brought to the same level, or as nearly so as possible. This is effected by cutting down the larger boats, or loading them until they are sufficiently deep in the water; this latter expedient increases the strain on the cable, and should not be resorted to in a strong current. In the smaller boats the gunwales must be raised; or a trestle, composed of a bottom and cap sill united by stanchions of the proper length, is placed in the axis of the boat, and kept vertical by braces.

The balks, when timber of sufficient dimensions can be procured, should be lashed over both gunwales of the two boats on which they rest. If the timber is not sufficiently long to admit of this arrangement, the following course is adopted: The balks of the first bay rest on both gunwales of the first boat; in the second bay, the odd-numbered balks rest on both gunwales of the first and on one gunwale of the second, and the even-numbered balks, on one gunwale of the first and on both gunwales of the second; the odd-numbered of the third bay rest on both gunwales of the second, and on one gunwale of the third, boat, etc.

If a bridge, thus made, is subjected to the action of waves, the oscillating motion produced will soon loosen the balk-lashings

and destroy it. To avoid this it will be necessary to make use of a saddle, as in the ponton bridge.

When anchors of sufficient size can be procured, the anchoring of this species of bridge does not differ from that of the ponton bridge. When this is not the case, some of the following expedients may be adopted:

Anchoring panniers may be used. They are conical gabions closed at both ends, with a pole passing through the axis. A hole is left in the side of the cone, through which the pannier is filled with stones; the hole is then closed with twigs, and a cable is attached to the end of the pole furthest from the pannier. It is cast in the same way as an ordinary anchor.

A strong box filled with stones or gravel may be employed. A common harrow loaded with stones forms a good anchor. The best anchorage is formed by driving a row of piles above the bridge. This method possesses the advantages of bringing a horizontal instead of a downward strain on the cable, and of protecting the bridge against injury from floating bodies.

Timber raft.—(Plate XV, Fig. 10.) Employ the largest and longest timber, giving at least thirty-five feet length to the raft. Shorter than this will not have sufficient stability, but will be subject to dangerous oscillations, especially in a rapid stream.

Squaring the timber will be worse than useless. Any irregularities, such as branches and knots, should be trimmed off. The raft must be built in the water. Select a place where there is little current and where the bank slopes gently to the stream.

It is to be observed that there are very few varieties of timber in this country which possess the requisite buoyancy when green. The timber is thrown into the water and moored to the shore, at a place suitable for building the raft, and where the current is not rapid. After the position which the stick naturally assumes in the water has been ascertained, the end which is to be up stream when in the raft is drawn up on the shore and the lower side is bevelled into a whistle shape, so as to present less obstruction to the action of the current.

The timber is then arranged in the position it is to have in the raft—the butts alternately up and down stream, and the upstream ends forming a right angle, salient up stream.

Suppose the case of a raft to be composed of twenty logs, forty-seven feet long and averaging twelve inches in diameter.

The first log is brought alongside the shore, and the end of a

plank or small trunk of a tree *a a* is spiked to it, about three feet from each end; it is pushed off a little, and a second log is brought up under the transoms and in close contact with the first.

The second log is spiked like the first, and so on for each of the remaining logs, care being taken to alternate the butts, placing the whistle ends up stream with the bevel underneath, and to spike the transoms perpendicularly to the logs. When the current of the river in which the raft is to be used is very gentle, the up-stream ends may be on a line parallel to the transom; but if rapid, they should form a right angle salient up stream, the vertex being in the middle log.

When the bank is too steep to admit of this construction the trees may be floated into their proper positions, lashed together, and the transoms spiked on. If the logs are nearly of the same size the centre of gravity will be near the centre of the raft.

Two additional transoms are spiked at equal distances from the centre of gravity of the raft and at a distance apart equal to the width of the roadway or platform.

The transoms should be about 8 inches wide by 6 inches thick. If square timber can not be had, saplings 7 or 8 inches in diameter may be used. They should have a bearing on all the logs forming the raft. To effect this, the larger logs should be cut down with an adze, and those too small be blocked up to the transom. The four transoms may be fastened to the logs either with spikes or wooden pins; or each log may be lashed by passing a rope around it and the transom, and twisting it tight with a rack-stick.

When a platform is to be constructed on the raft, intermediate transoms are laid, and at a distance apart depending on the strength of the planking.

The size of this platform must be regulated by the buoyant power of the raft. A single course of logs will not have sufficient power to sustain troops enough to cover its whole surface.

When this is required, several courses of timber are employed, each perpendicular to that below it, and the whole firmly united with pins or lashing.

When the raft is to be used in a bridge, the two intermediate transoms are separated by a distance a little less than the length of the chess, and placed at equal distances from a point somewhat astern of the centre of gravity of the raft—in order to correct the downward action of the cable on the bow.

On these transoms, three supports *d d d* are spiked to receive the balks. A piece of plank is nailed on the bow to prevent the cable from getting entangled in the raft.

When the logs are less than thirty-five feet in length, the following construction is employed:

The small ends of half the trees are bevelled; then a raft is formed with the butts all down stream; in other respects it is similar to that described above.

The remaining trees are then brought butt to butt with those in the raft, and fastened to them with iron clamps or dogs, or by spiking a piece of plank across the two. A transom is spiked on the stern, and the two central transoms as in the preceding example. A transom *g* is then placed a little forward of the centre of gravity of the partial raft *a*, and a transom *k* a little astern of the centre of gravity of the partial raft *c*. The strong timbers *d d* extend over the four interior transoms. These timbers support the balks and diffuse the load over the entire raft, without tending to disunite the partial rafts.

For use in a bridge, a raft should be able to sustain at least fifteen thousand pounds. The same expedients are employed for the anchorage of rafts as for boats. It must, however, be borne in mind that a raft offers a much greater obstruction to the current than a boat, and that the strain on the cables is proportionally greater.

Rafts are sometimes constructed for flying bridges in the form of a lozenge—the acute angles being about 55°—so that when two of the sides are parallel to the direction of the current, the up-stream side, which in this form is the only one acted on by the current, is in the most favorable position.

Raft of casks.—This raft may be constructed by forming a frame of timber to contain the casks. (Plate XV, Fig. 9.)

The frame consists of four longitudinal pieces halved into four transoms. The long pieces must be at least twenty feet long, and their distance apart be a little less than the head diameter of the casks. The under edges are bevelled so as to give them a good bearing on the casks.

In default of square timber, poles may be used in the construction of the frame. The string pieces and transoms may be spiked or lashed at their points of junction.

The four exterior casks in the raft should be lashed to the frame, otherwise they may be carried off by the current when the raft lurches.

Temporary trestles.—In case the number of trestles accompanying the train should prove insufficient, it is easy to construct rough trestles of a pattern similar to the adopted form. Nothing is required but the lumber, a few carpenters' tools, and six-inch spikes; all the other iron work may be dispensed with, and rope may supply the place of chains. Men competent for such work are always to be found in an engineer company.

A trestle may be composed (Plate XV, Fig. 7) of a cap, about 15 feet by 9 inches by 9 inches, of four legs, of two lower and two upper traverses, and of four braces.

The cap is notched 18 inches from the end, to receive the legs; the notch is 5 inches wide and 1 inch deep.

The legs should be from five to six inches square; a shoulder is made to fit the notch in the cap; the spread is one-quarter the height; the inclination in the other direction is about one-sixteenth. The leg is spiked, pinned, or bolted to the cap. The lower traverse is 5 inches by 1½ inches, and is dovetailed into the legs at about one quarter of their height from the ground.

The upper traverse, which is nailed on the outside of the legs and against the cap, is 6 inches wide and 1½ inches thick.

The braces are 4 inches wide by 1½ inches thick, and are spiked to the cap and legs.

The above dimensions and method of construction are not absolute, but are given as a guide to be followed as closely as circumstances will permit.

Trestles are often constructed after one of the forms represented by Figs. 11, 12, and 13, Plate XVIII. Fig. 11 is the simplest and is generally the easiest to make; but when there is a lack of heavy timber, one of the other forms must be adopted. If Fig. 13 is used for railroad purposes, the vertical posts should come under the rails—otherwise the spaces between the posts should be equal. The posts are fastened to the caps and sills by dowels, tenons, or cleats. The latter are the easiest and quickest to use, and, although not neat to the eye, they meet every necessity in a temporary bridge. A company of pontoniers well equipped with 10-penny nails, 4 to 6 inch spikes, cross-cut and hand saws, axes and hatchets, can in a few hours thus improvise a good trestle bridge over any stream with a gentle current and not over 6 feet deep.

Small trestles are sometimes made, as in Fig. 14, Plate XVIII, with a cap and two legs at each end, spread apart perpendicularly to the cap—forming what carpenters term horses. Such

trestles can not easily be made to fit irregular bottoms, and they are less simple in construction than the rectangular-shaped. When used, each pair of legs should rest on a short sill.

Trestles may be made of round timber, care being taken to level the upper surface of the cap.

When the trestles are to be placed on a soft bottom, a flat sill should be spiked under the legs on each side.

Constructing the bridge.—In constructing the bridge when the water is less than four feet deep, the trestles may be carried to their places by men wading in the stream; an abutment is formed as for an ordinary bridge; the trestles are placed with their caps parallel to the abutment sill and about thirteen feet apart.

When the water is too deep or too cold to allow this method to be pursued, the bridge may be constructed as follows:

The abutment sill (Plate XV, Fig. 6) being placed, the first trestle can usually be placed by hand; the balks are then laid and covered with chess to within one foot of the trestle; a roller is laid on the bridge; on this are laid two beams, from thirty to forty feet long and six or seven inches square. The trestle is placed upright with its cap resting on these beams, to which it is firmly lashed. The pontoniers bear down on the other ends of the beams, at the same time pushing until the trestle is rolled out to the proper distance; they then suddenly release the beams, dropping the trestle into its place.

If the trestle does not stand firmly, or if the cap is too much inclined in consequence of the unevenness of the bottom of the stream, a man must walk out on the beams and sound with a pole the depth of water where each leg is to be placed; having thus determined the proper length of the legs, the trestle is hauled on the bridge, the legs are cut down as required, and the trestle is replaced. The flooring balks are slid out on the two beams, adjusted, and covered with chess.

When a boat or raft (Plate XV, Fig. 5) can be procured the trestles are placed with much less labor.

The boat is brought along-side the last trestle placed; two balks are laid from the bridge, resting on a saddle or the outer gunwale of the boat; the side of the trestle-cap is laid on the balks, the legs extending over the outer gunwale of the boat. The boat is pushed off by means of the balks until it arrives at the proper position for placing the trestle, which is then righted,

If it has not a good bearing on the bottom, it is hauled into the boat and the legs are cut to the proper length.

The bridge may be entirely built of round timber. The caps should be from ten to twelve inches in diameter; the legs, at least six inches; the balks, seven or eight inches, and faced on the lower side where they rest on the trestles, so as to bring their upper surfaces on the same plane. The covering may be of strong hurdles.

Pile bridges.—Pile bridges are frequently employed after an army has effected the passage of a river, either for the purpose of rendering the bridge equipage disposable for other service, or to increase the facilities of communicating with the base.

When the ordinary pile driver can be procured, these bridges are constructed by methods too well known to require any description here.

When these engines can not be obtained, a temporary pile driver may be constructed from the material contained in the bridge train, in the following manner, (Plate XVI, Figs. 1, 2, and 3:) A raft is formed of two pontons covered with balks and chess; on the side rails are laid two balks *b b*. They are secured to the former by bolts and lashings. Two balks *c c* are placed vertically, notched two inches deep, and bolted to the balks *b b*. They are stayed by the balks *d d* and the guys *r r*, and by a cap *f*. The hammer *h* is a log of heavy wood, about sixteen inches in diameter and four or five feet long, smoothed on two opposite sides to fit between the balks *c c*. Two pins are driven into the hammer on each side, near the top and bottom, to serve as guides; a single block is attached to the cap by a ring-bolt or rope. Through this block a fall is passed, provided with a hook at one end for the purpose of attaching it to the hammer. To the other end, a number of balk lashings are attached, by means of which the hammer is worked in a manner similar to the ringing pile driver. To manœuvre this pile driver, the raft is held in position by three anchors, the cables from two of which are attached to the bow, and that from the third to the stern, of the raft.

To construct the bridge, rows of piles are driven parallel to the current of the stream. Each row should contain from four to six piles, from three to six feet apart. The space between the rows should be from fifteen to thirty feet, depending on the size of the timber used for flooring joist. After the piles are

driven, they are cut off in a plane about two feet above the highest water-level.

Fig. 4, Plate XVI, represents a pier of such a bridge; *b b* are the piles; *a*, a cap of square timber secured to the piles either by 2-inch hard-wood dowels, or by tenons; *d d* are fender piles driven about five feet outside the extreme piles of the pier, and drawn in and secured at top to the cap. They act as braces to prevent oscillation, and as fenders to protect the bridge from floating bodies. The flooring of the bridge is constructed in the usual manner.

A light pile bridge suitable for infantry may be constructed over shallow streams without the use of a pile engine. The piles, which should be about six inches in diameter, are driven with mauls, as represented in Plate XVI, Fig. 5.

PRESERVATION OF BRIDGES.

When the current is rapid, the bridge is protected from the shock of floating bodies by establishing a guard of observation above the bridge, to arrest these bodies; by placing a floating stockade obliquely across the stream; or by constructing the bridge by rafts, and withdrawing that part which is menaced, thus allowing the body to float past.

The guard of observation is stationed about one thousand yards above the bridge. It is provided with boats containing cables, anchors, grapnels, hammers, etc. These boats are stationed at different points across the stream.

As soon as a floating body that may endanger the bridge is observed, a boat hastens toward it, fastens a line to it, and endeavors to tow it ashore. If unable to do so, the line is made fast to an anchor, which should be so cast that the first strain on the cable will be oblique to the direction of the current; the body will then swing around and lose part of its momentum, thus relieving the cable of a portion of the strain.

The boats should also be provided with chains and grapnels, to tow burning bodies.

The floating stockade is constructed of trees united by chains, and forming a continuous barrier to floating bodies. Its direction should form an angle of about 20° with the current, which will require the length to be two and three-quarter times the width of the river.

Each piece is formed of one, two, or three trunks lashed together.

As a stockade is not a reliable protection, it should be established at a considerable distance above the bridge.

A guard should always be placed at the bridge, from which a sentinel is posted at each extremity, and, if the bridge is long, at intermediate points.

These sentinels should turn out the guard when the bridge is in danger from any cause. They will see that the troops march at the route step; that cavalry dismount; that the troops and carriages halt when the bridge commences to oscillate dangerously; that too heavily loaded carriages do not enter; that the right of way for vehicles desiring to cross in opposite directions is properly regulated; and that not more than five or six head of cattle enter at the same time.

The officer in charge of the bridge will frequently inspect the cables, to see that they are not chafing and that the anchors do not drag. He will cause rack-lashings to be tightened when they work loose, and pontons to be bailed when they leak or ship water.

There should be formed, on the shore near the entrance to the bridge, a depot of spare balks, chess, cordage, etc., by means of which any injury to the bridge may be promptly repaired.

CHAPTER V.

BRIDGES WITHOUT THE BRIDGE EQUIPAGE.

In campaigns it often becomes necessary for pontoniers to construct high bridges of trestle-work, for the purpose of replacing destroyed railroad or highway bridges. A few of the forms usually adopted for such trestles will now be indicated.

TRESTLE BRIDGES FOR RAILWAYS.

The trestle.—The railway trestle bridge represented in Fig. 1 and Fig. 2, Plate XVIII, is the one generally adopted in the United States, although slight variations in unimportant details will often be found. It consists of a cap, a mud-sill, two vertical posts, and two inclined ones. The vertical posts sustain the load—the inclined ones being merely used to brace the combination, and to prevent injury from lateral motion in the bridge.

The length of the cap is fixed at 16 feet, as that length gives room for a walk on either side of the track; if economy demands it, however, the length of the cap may be reduced to 12 feet, with a corresponding reduction in the other parts. The vertical posts are placed 5 feet apart between centres, and come directly under the longitudinal joint in the track stringers. The inclined posts are attached at distances of one foot from the outer extremities of the cap; they receive the slope of one base to four perpendicular. From these conditions the length of the mud-sill is deduced. The posts are connected with the cap and the sill by tenons, 3 inches thick 6 inches long and of the width of the post, fitting into corresponding mortises, and fastened by $1\frac{1}{4}$-inch tree-nails or pins. It is usual to make the holes in the tenons about one-eighth of an inch nearer the shoulders than their exact place, so that the pins may draw the two pieces up to a close-fitting joint.

To bind all the parts of a trestle or *bent* firmly together, horizontal planks, 3 inches by 12 inches, are spiked on in pairs at every 15 or 20 feet, and diagonal braces are fastened on each side. The latter need not be so wide as the horizontal ties.

Should square timber be unattainable, the trestle may be con-

structed of round timber, provided that the smallest diameter be not less than 10 inches. The bracing may be made by spiking on poles not less than 4 inches in diameter, care being taken to face both posts and braces where they intersect, so as to secure a firm connection. With round timber, the connections between posts and caps may be made by using 2-inch or 3-inch oak dowels, 12 inches long, or by spiking on a couple of cleats. When green timber is used throughout, the bracing requires constant readjustment, as the shrinkage enlarges the spike-holes, and sometimes even draws the spikes. If seasoned bracing can be procured, green timber will generally answer well enough for everything else, although its strength is somewhat less than when dry.

When trestles are less than 40 feet in height, the posts are generally of one piece. It is always advantageous to have them so, but long lengths of timber cannot always be procured. In such cases the trestle must be made of parts or sections. To build the trestle represented in the drawings, supposing long timber unattainable, we would replace the horizontal ties by caps of the same cross-section as the upper cap—thus transforming the trestle into three smaller ones, placed vertically over each other, the cap of the lower answering for the sill of the next higher, and so on. Each subordinate trestle may be framed separately, and then hoisted into place; or the upper sections may be constructed by piece, after the lower have been put in position. The subordinate trestles are connected together by mortise and tenon, by cleats, or by dowels, as may be deemed most expedient. As far as practicable, differences of level in the site are provided for in the lower sections, and the upper sections are made alike.

To raise a trestle.—Trestle bridges and viaducts are always commenced from one or both ends, thus beginning with the shortest trestles, which are easily placed in position. As fast as the trestles are raised, the connecting stringers and track are laid; and thus a platform is formed from which to raise the next trestle. It is generally considered advantageous, both in dry and wet work, to frame and complete a trestle before any attempt is made to raise it. This is done as near as possible to the place where it is to be used, and it is conveyed to its exact position by the most convenient method. In wet work, the trestle is pushed into the water and floated to where it is wanted. In dry work, the trestle is dragged to its place, its sill is placed

so that after raising it will be in its exact position, and the trestle is then raised by ropes and poles; in this case but half of the weight is lifted. In wet work, however, the entire weight of the trestle must be raised. Tall and heavy trestles are generally raised by means of balance beams, with single or double blocks and a windlass or crab.

Figs. 3, 4, 5, and 6 of Plate XVIII show a trussed balance beam with windlass, used for raising heavy trestles. Two of these are used together, resting upon the caps of the two last trestles raised, to which they are securely fastened by ropes or chains. Blocks are placed upon the last trestle so as to raise the outer ends of the beams, and the fastenings of the inner ends are so made as to prevent any slipping in either direction. The outer extremities are fitted with pulleys, and they project so far that the pulleys come exactly over the place of the trestle to be raised. The balance beams are from 6 to 8 feet longer than two bays of the bridge. A rope 1½ inches in diameter is fastened by one end to a ring on the under side of the beam, whence it passes downward through a movable block, thence upward over the pulley, thence through a hole in the strut, between the truss rods, to the windlass. Sometimes the latter is dispensed with, and the rope, passing through a snatch-block below or on one side of the track, is hauled by horses; or, when available, the traction of a locomotive is employed. Double blocks are sometimes used in raising very heavy bents; but they increase the time of raising, and they require an additional elevation of the projecting end of the balance beam. If the beams were not trussed, they would require so great a section as to be unmanageable. The calculated weight of the trestle represented in the plates, supposing all the wood work to be made of white pine, is 9,840 pounds.

In rough temporary wet work, if long timbers can be procured they are sometimes raised singly, held in place by temporary braces, sawed off at the proper heights, and finally capped. The caps and posts are connected together by cleats or dowels; and the trestle is then braced in the same manner as the one represented.

Where the ground is very firm, the posts may rest directly on the soil; but it is safer and better to use a crow's foot, (Plate XVIII, Fig. 10,) made of two pieces of stuff, 4 feet by 12 inches, fastened to each other at right angles, and connected with the post by dowels or cleats, or both. On irregular rocky bottoms,

neither sills nor crow's feet can be used, and it is necessary to feel around with the posts for the best foothold that can be found. Wherever there is any danger of scour, sills should be used. They should be protected from undermining by loaded fascines or loose rock. For permanent trestles they are indispensable.

In building viaducts over irregular ground, particularly on the side slopes of hills, it is not always possible to use continuous sills. In such cases a sill must be placed under the two vertical posts, and crow's feet, resting on levelled benches, under the inclined posts. All the posts must be firmly connected by horizontal braces placed as near the ground as practicable.

In building a trestle in deep water it is necessary to load the lower portion with railroad iron or other heavy materials. They should, if possible, be fastened to the posts, as they might tear off the sill if attached to it.

Connection of track and trestles.—In connecting the track with the trestle-cap care must be taken that no longitudinal motion can be caused by the *crawl* of the locomotive, (its tendency to push the track from under it;) nor any transverse motion along the trestle cap, which would destroy the alignment of the track. It will be seen (Plate XVIII, Figs. 1 and 2) that the first danger is guarded against by spiking on cleats, with 2-inch shoulders, on each side of the track stringers where they cross the cap; and that the second is met by the block spiked on between the stringers, and by the ties. A valuable additional protection against the crawl of the locomotive is obtained, by providing that the track stringers of the abutment bays shall abut firmly against masonry, or some other fixed support. This precaution should never be neglected.

The two sticks that form one track stringer should each have the length of two bays of the bridge, and they should be firmly connected by $\frac{3}{4}$-inch bolts passing through the cleats, and should break joints. It is advantageous, when time and circumstances permit, to bolt the stringers to the cap, which of course would render cleats unnecessary. The use of the latter, however, is much more expeditious, and it has therefore been preferred for military bridges.

Longitudinal bracing.—The trestles are connected together (Plate XVIII, Figs. 1 and 2) by longitudinal ties, 4 inches by 8 inches, resting on the horizontal ties of each trestle, and fastened by two spikes to each post. Diagonal bracing between the trestles may be used, and thus greater stability be secured;

this is essential where trestle bridges are to be crossed at a high rate of speed.

Cross-ties and guard rails.—The cross-ties for a bridge are the same as those used on land, and are 8 feet 6 inches long, 8 inches thick, with 8 inches face. Notches, 2 inches in depth, connect them with the stringers, but they are not otherwise fastened. This arrangement is made to permit the ready removal of a defective tie. Between the ties are placed short pieces of plank set on edge, or short diagonal braces, to prevent them from being pushed up into a heap when a car jumps the rails; and wooden guard rails, 4 inches by 8 inches, (with the wide side down) are spiked on the ends of the ties. When these precautions are taken, a train may run off the track while on a bridge and yet not break through. Several such incidents occurred during the late war. Care should be taken to see that no shoulder is left on the inside of the joint between two guard rails, lest a car wheel striking it should mount the guard rail and fall from the bridge.

Temporary trestles as scaffolding for trusses.—In military operations it often becomes necessary to replace a destroyed railway bridge by a trestle bridge, which must be used for a few months, but which is to be replaced as soon as possible by a permanent truss bridge. In constructing such a trestle bridge, it is important so to design it that it may serve as the false work, or scaffolding, for the truss bridge. Figs. 7, 8, and 9, Plate XVIII, represent a bridge so constructed. It is designed to receive a Howe truss bridge of 180 feet span. Comparing it with Fig. 1, we see that the cap has been lengthened to 24 feet, which accommodates the truss and secures a run-way for workmen outside of it. The inclined posts have been so placed as to come a little outside of the middle of the bottom chord of the truss. In a Howe bridge of 180 feet span, and 11¼ feet panel length, we have the following dimensions:

Depth of track stringer	12 inches.
Depth of floor beam	14 inches.
Depth of bottom chord	14 inches.
Total	40 inches.

The trestle bridge should be constructed so as to use the same track stringers as the Howe bridge, and the track should be raised so much above the trestle cap that the floor beams of

the truss bridge may be passed under the stringers of the trestle bridge without disturbing the track or the trains. We must, therefore, place the top of the track stringers 40 inches above the trestle cap. This is done by resting them upon a bolster, 14 inches in depth, which rests on a block also 14 inches in depth, placed upon the trestle cap. The position of the truss and its floor beams is shown in outline.

Ice-breakers.—When trestles are placed in running streams, which at times are encumbered with drift-wood or ice, it is advisable to construct ice breakers, and to board up the lower part of the trestles to high water. A group of piles chained together just above the trestle, forms an excellent ice-breaker; it should not be connected with the trestle.

Pile foundations.—Where foundations are so bad that the sill of the trestle cannot be laid on the natural surface, it must rest on piles driven to a firm subsoil, and sawed off just below low water.

Load on a railway bridge.—The load on a narrow-gauge railway bridge, with spans of 16 feet, is generally taken at 3,000 pounds per running foot, making 48,000 pounds on a bay—which really exceeds the maximum load in practice. A white-pine track stringer, 16 feet between bearings with a cross-section of 7 inches by 14 inches, will safely bear a distributed load of 23,324 pounds. The bridge will, therefore, safely bear 93,296 pounds. With track stringers 7 inches by 12 inches, as in Figs. 7, 8, and 9, Plate XVIII, the bridge will safely bear 68,544 pounds, without taking into account the increase of strength given by the bolsters. In both cases, therefore, we have more than the required security. These "safe weights" have been calculated with 4 as the factor of safety.

STRENGTH OF TRESTLE BRIDGES.

The same principles that govern railway trestles hold for the smaller structures built for the passage of the ordinary vehicles of an army—which are usually composed of cap, sill, and two, three, or four posts. The principal point to be examined is the strength of the posts and caps. The former sustain forces of compression acting through their axes; the latter are beams resting upon two or more points of support, sustaining a transverse strain at, say, five equidistant points. No absolute dimensions for these parts can be given, as their sizes must vary with the character of the wood used, and with the height of the

trestles; the dimensions for any unusual structure must, therefore, be computed.

Strength of posts.—There are many formulas given in the text-books for the strength of wooden pillars, the majority of which are too complicated for prompt use in the field. For short posts, the breaking weight in pounds is obtained by multiplying the area of the section in square inches by the numbers given in the accompanying table; (it should be remarked that authorities differ greatly as to the numerical values of some of these coefficients.) For a long post, divide its length by its mean thickness, both expressed in inches, and after getting its strength from the first table, divide the result by the proper number obtained from the second table. Long posts yield by flexure under less than the breaking weight due to the cross-section alone—hence the reduction necessary in the strength as obtained directly from the first table.

These tables are designed to give the weight that will just break the posts in question. To obtain the safe weight we must divide the breaking weight by 10, which is the usual factor of safety for wooden pillars.

Rectangular wooden posts under compression.

Material.	Breaking weight per square inch.	Material.	Breaking weight per square inch.	Material.	Breaking weight per square inch.
	Lbs.		*Lbs.*		*Lbs.*
Alder	6,800	Elm	6,500	Red pine	5,400
Ash	8,700	Fir (spruce)	6,700	Poplar	4,500
Beech	7,500	Oak (Quebec)	5,000	Red spruce	5,400
Birch	6,000	Oak (English)	8,000	White spruce	4,000
Cedar	5,800	Pitch pine	8,000	Sycamore	7,100
Elder	7,400	Yellow pine	6,700	Walnut	6,500

Reduction for long posts.

Length ÷ least thickness	12	18	24	30	36	42	48	54	60
Divisor	1.2	1.6	2	2.8	4	5	6	8	12

Strength of caps.—For beams resting upon two supports and uniformly loaded, we have the following formula:

$$W = \frac{8\ k\ b\ d^2}{l}$$

If loaded only at the middle, we have

$$W = \frac{4\,k\,b\,d^2}{l}$$

The cap of a trestle for a highway bridge may be considered as occupying a mean place between uniformily-loaded and centrally-loaded beams; and we will assume for it the formula

$$(1.) \qquad W = \frac{6\,k\,b\,d^2}{l}$$

In which:

b = the breadth in inches.

d = the depth in inches.

l = the length in feet.

k = a constant obtained from the following table:

Values of the constant.

Material.	k.	Material.	k.
Ash	170	Canadian oak	147
Hickory	270	White pine	135
Chestnut (sweet)	170	Yellow pine	150
White oak	200	Teak	205
English oak	120		

These values of k give the weights under which beams *will break*. To get the weights that they will carry safely, we must divide by the factor of safety—which for beams is generally taken at 4, though any required amount of safety may be secured by using a larger factor.

To compute the bridge dimensions.—The weights to be carried being always determined in advance, we have simply to make the trestle conform to them. Assuming the same length of bay (20 feet) that is used in ponton bridges, and the same maximum weight per bay to be sustained, which is 16,000 pounds, we have the necessary data for calculating the sizes of the timber to be used.

To get the cross-section of the different parts of the bridge, we would, therefore, have a maximum load on the trestle cap of 16,000 pounds, distributed between five places, and on each post (assuming that the trestle has two) a maximum load of 8,000 pounds, which we will increase to 10,000 pounds, to provide for an unequal distribution.

Hence, to get the cross-section of a *post*, (*leg*,) multiply 10,000 by 10, the factor of safety for posts, and divide by the tabular breaking weight of the kind of wood to be used. The square

root of the quotient will be the side of the cross-section. Divide the length of the post in inches by the side thus determined, and if the quotient is less than 12 we have the proper section. If it be 12 or more, the cross-section is too small; and it must be increased by successive approximation, until the product of the new area of cross-section by the tabular breaking weight, divided by the divisor of reduction for long posts corresponding to the new dimensions, becomes exactly equal to 100,000.

To get the cross-section of a *beam*, (cap,) multiply 16,000 by 4, the factor of safety for beams, and substitute the product for W in equation (1). Replace k and l by their respective numerical values, and solve the equation with reference to $b\,d^2$. Assume any value for one of them, and deduce the corresponding values of the other until a satisfactory cross-section is found.

The cross-section of the *bridge stringers* and *flooring plank* may be computed in a similar manner for any desired bearings.

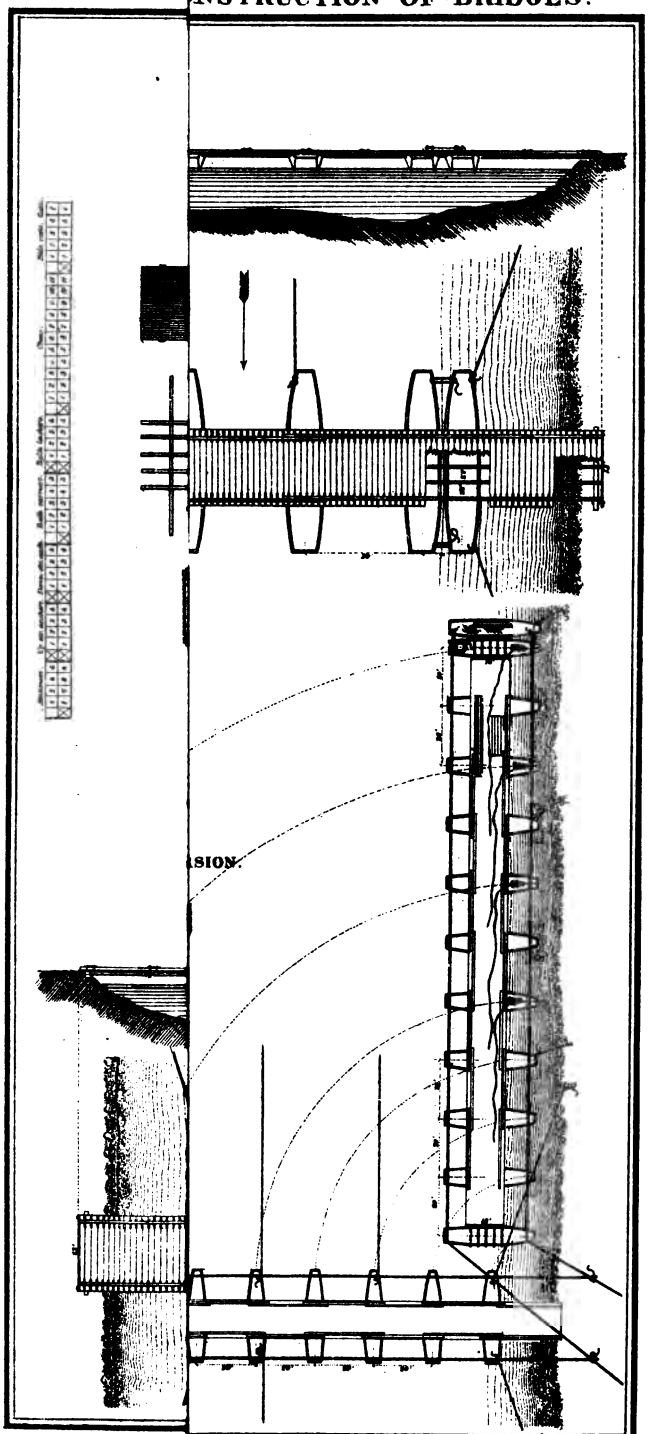
Bracing of trestle bridges.—In building trestle bridges, pontoniers must particularly guard against the trestles falling down like a row of bricks. Such accidents happened more than once during the late war; the following record of one that occurred to the Austrian army will give additional proof of the necessity of precaution in this respect:

In the year 1839 the Fourth Regiment of Austrian Imperial Pioneers (sappers, miners, and pontoniers) was building a trestle bridge, 1,021 feet long, over an arm of the Danube near Vienna, in connection with a field manœuvre in which the third and fourth divisions of the fifth army corps participated. The abutment sills were carefully laid and fastened in place, and heavy cables were run along the up and down stream ends of the trestles, to which they were securely fastened. The cables were drawn taut by block and tackle, and were then securely fastened to large trees. Four regiments and two battalions had passed safely. While a rifle regiment was crossing the bridge, the abutment sills yielded, the cables broke, and the whole bridge fell down like a pack of cards. About seven hundred men were on the bridge at the time, of whom two hundred and sixty were drowned.

To prevent such accidents, diagonals are sometimes inserted between the trestles. This may be done by driving poles in a slanting direction into the bottom of the river and then spiking them to the caps, or by spiking diagonals on the trestle posts.

Both methods are shown on Fig. 15, Plate XVIII. The continuous passage of troops in the same direction has a tendency to overthrow the trestles, particularly if the top of the bridge is not level, or if it is approached by a steep descent. The method adopted by the Austrians will accomplish the object if a strong enough cable be used; but the difficulty is, to compute its size—which evidently must rapidly increase with the length of the bridge.

The carpenter-horse trestles (Plate XV, Fig. 7, and Plate XVIII, Fig. 14) are not subject to this danger of rotation, and they may sometimes be used advantageously in connection with the rectangular trestle.



THE ABUTMENT BAY.

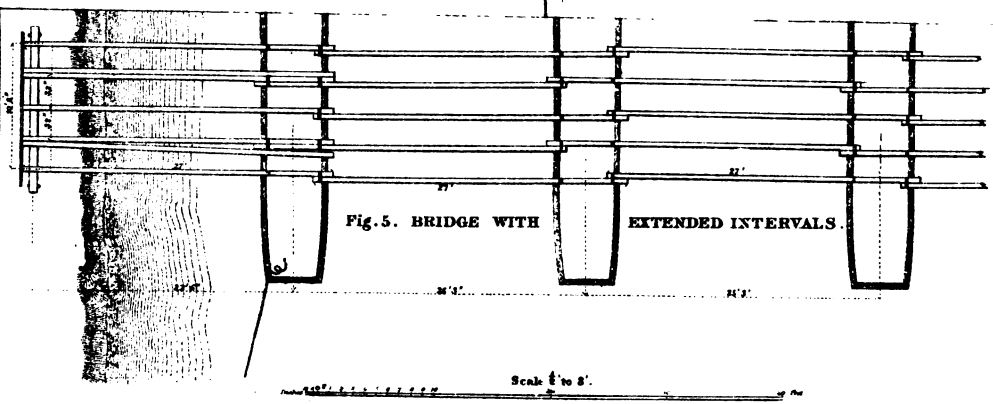
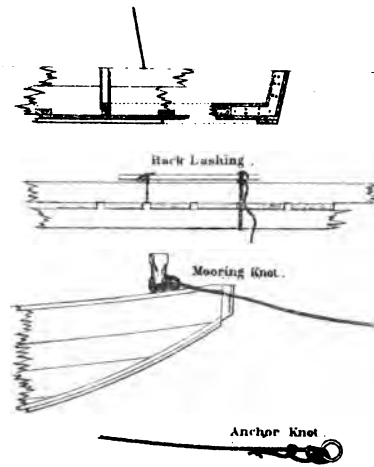


Fig. 5. BRIDGE WITH EXTENDED INTERVALS.

Scale ⅛ to 8'.



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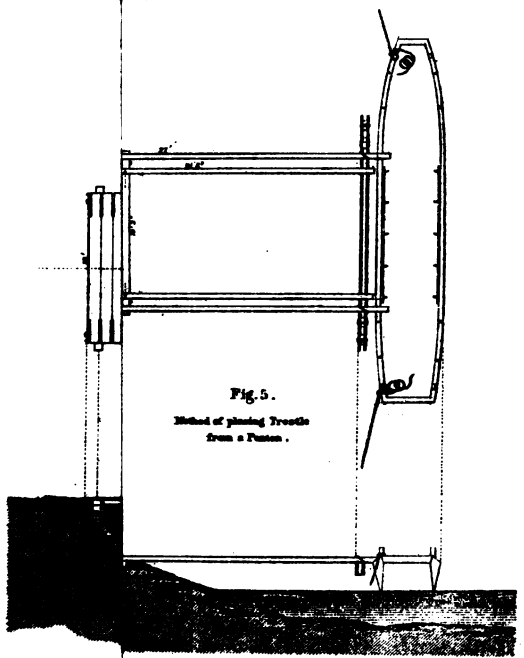

Fig. 5.
Method of placing Trestle from a Pontoon.

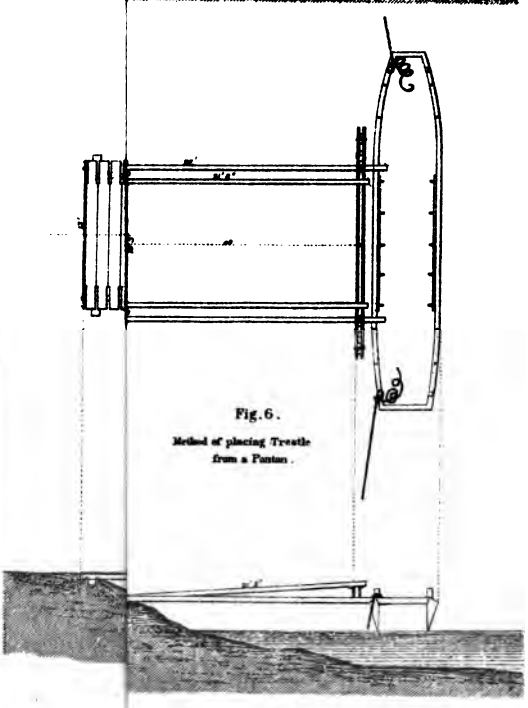

Fig. 6.
Method of placing Trestle from a Pontoon.

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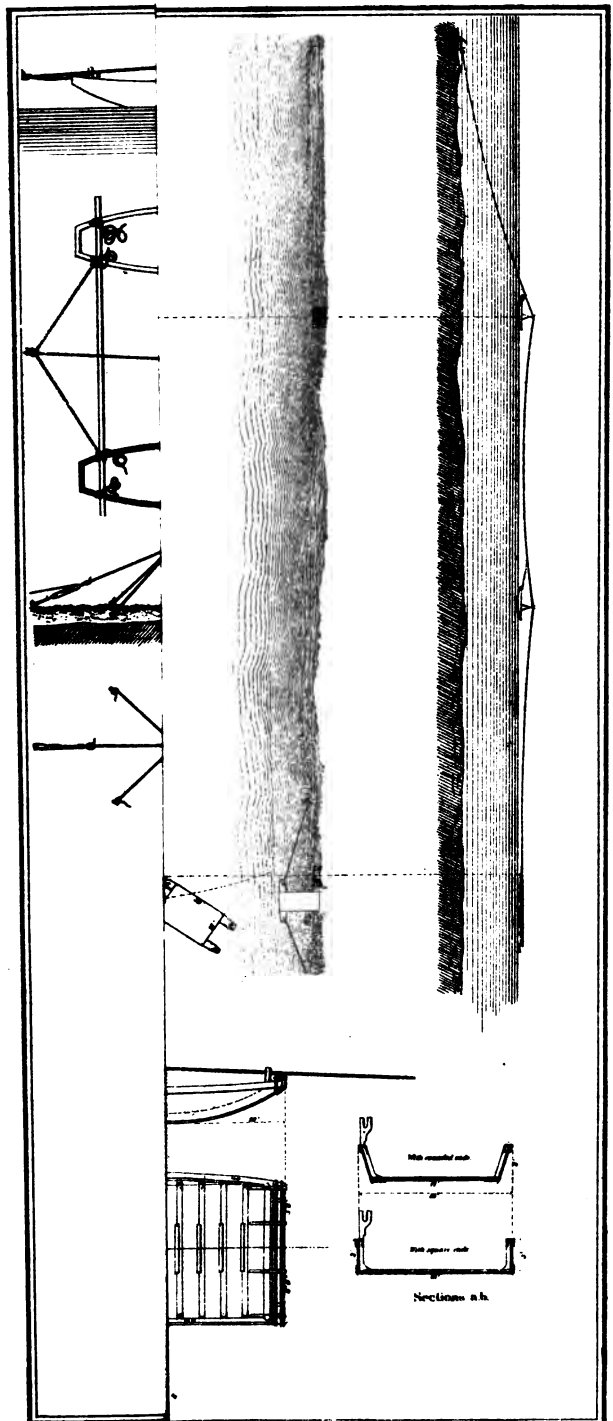

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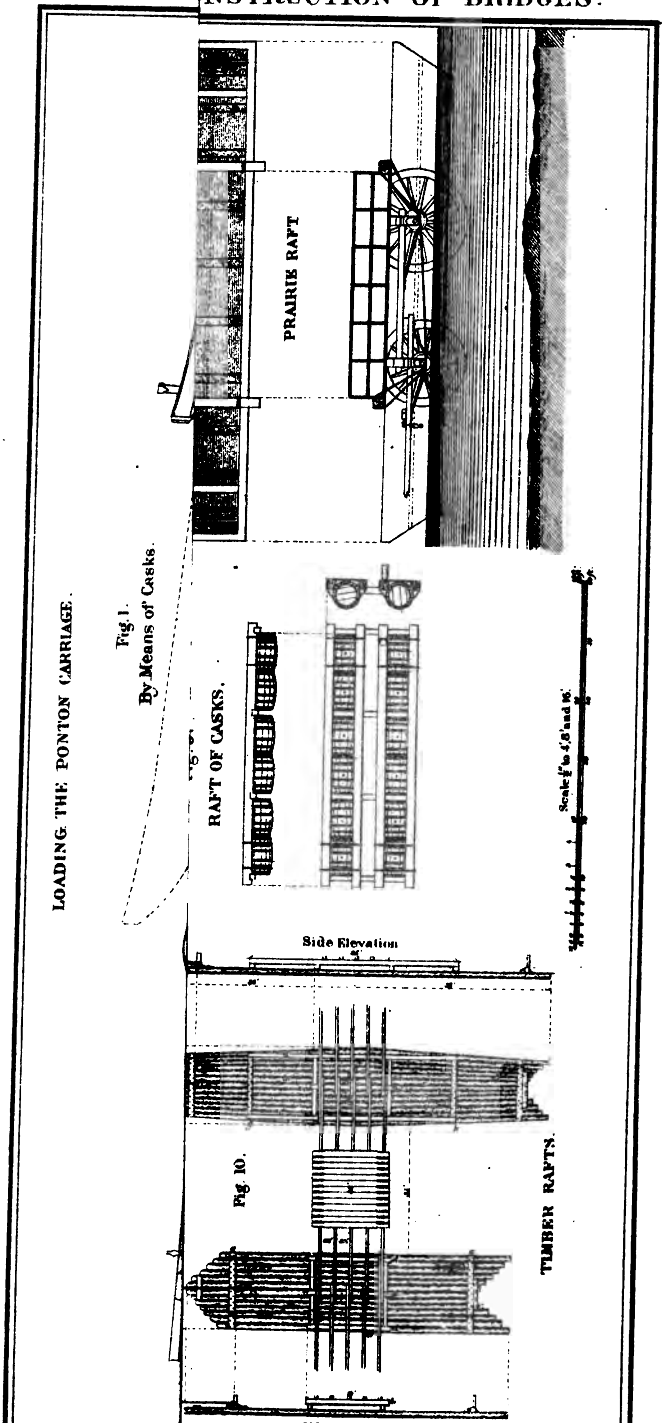

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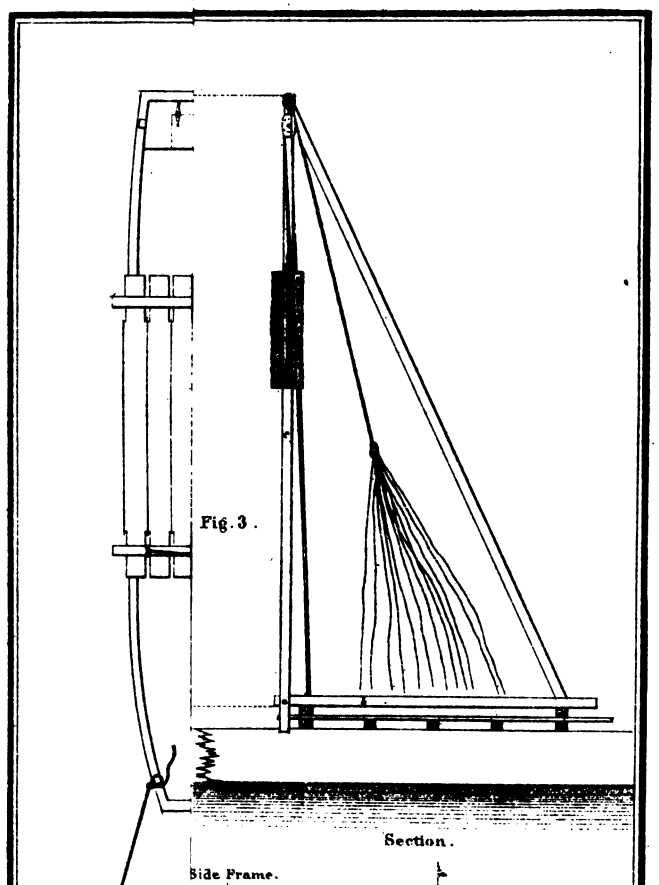


Fig. 3.

Section.

Side Frame.

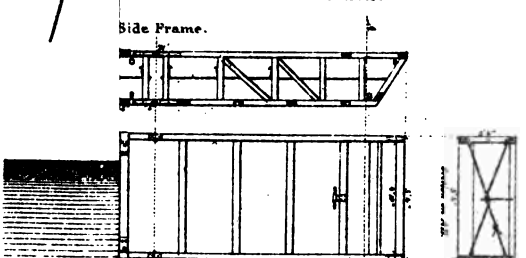
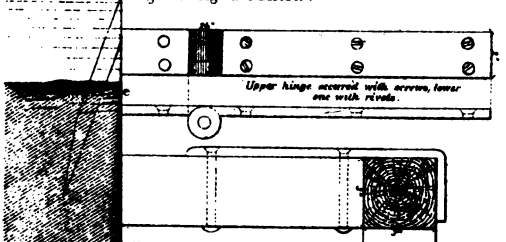


Fig. 6. Hinged Ponton.



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